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A Canadian Dynamic Controlled-Climate Test Facility

Feasibility Study - Summary Report

Prepared for the Transportation Development Centre
Transport Canada

by DSMA International Inc.
Toronto Canada

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The contents of this report represent the opinions and judgement of the Consultants, and do not necessarily reflect the official views or policies of Transport Canada.

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17. Abstract

This report presents the summary of three-phase feasibility study that was carried out for the creation of a new dynamic (airflow simulation) controlled-climate test facility in Canada. The facility would be used for research, development and testing of rail vehicles and other large equipment under controlled climate extremes.

During the first phase of the study, approximately 150 potential Canadian users of the facility were canvassed regarding level of interest and preferred test configurations and capabilities. Candidate users in the government, industrial and academic communities were polled. Detailed follow-up interviews were held with approximately fourty respondents.

The second phase of the study developed conceptual engineering designs of the proposed facility for three levels of testing capability. All designs centered on the creation of the facility as an add-on to the new National Research Council static cold room, and in accordance with information received during the survey phase.

The final phase of the study developed operational scenarios for the recommended facility concepts, and used these as the basis for a staged benefit/cost assessment. The study concludes with recommendations on the conceptual design and configuration of the facility, its location, and management/staffing. Projections of capital acquisition costs and operating costs are made. Recommendations are also made for marketing and design study activities for the facility.

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17. Résumé

Ce rapport est le résumé d'une étude de faisabilité en 3 phases concernant la construction au Canada d'une soufflerie aérodynamique à climat contrôlé, pour la recherche, le développement et l'essai de véhicules ferroviaires et de matériels lourds dans des conditions climatiques rigoureuses contrôlées.

La première phase de l'étude a consisté à faire un sondage auprès de quelques 150 utilisateurs possibles de la soufflerie envisagée, pour connaître leur réaction à cette idée, déterminer les utilisations qu'ils envisagent et évaluer l'ampleur de la demande pour ce type d'installation. Les milieux sondés ont été choisis au niveau du gouvernement, de l'industrie et des universités, et une quarantaine d'interviews personnelles ont été faites.

La deuxième phase a eu pour objectif d'élaborer des concepts portant sur trois schémas de réalisation distincts, mais tous axés sur l'idée d'adjoindre la soufflerie à l'installation d'essais climatiques statiques du Conseil national de recherches, et prenant en compte les résultats du sondage fait au préalable.

La troisième phase a permis d'élaborer divers scénarios d'exploitation applicables aux concepts retenus, et qui ont servi à jeter les bases d'une étude du rapport avantages-coût. L'étude conclut en proposant divers concepts et schémas de réalisation du projet, l'emplacement à retenir, ainsi que le mode de gestion et de dotation en personnel à adopter. Elle assortit chaque proposition d'un devis estimatif quant au coût de premier établissement et d'exploitation. Enfin, des recommandations sont faites concernant les études techniques et la promotion de l'installation.

18 Mots-clés			19 Diffusion
Etudes climatiques	Verglas	Chemin de fer	Le CDT dispose d'un nombre limité d'exemplaires
Modélisation	Givre	Chaleur	
Intempéries	Humidité	Matériel lourd	
Pluie	Ecoulement de l'air	Température	
Neige	Aérodynamique	Soufflerie	
	Installation d'essais	Banc dynamométrique	

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Finally, the efforts of DSMA Atcon Ltd. (D. Ferguson and W. Corke) in their role as sub-consultants during the user survey are acknowledged.

FOREWORD

This report is a summary of the final report of the Transportation Development Centre Controlled-Climate Test Facility Study. The study, commencing in June 1981, was conducted for the Transportation Development Centre (TDC) of Transport Canada under Department of Supply and Services Contract Serial No. OSD81-00023.

The study was carried out by the consulting engineering firm of DSMA International Inc. (DSMA), Toronto. The Consultants have had extensive experience in the design, construction and operation of climatic test facilities and wind tunnels, not only in Canada, but also in Europe and the United States. Major DSMA-designed climatic facilities are now in operation for such firms as Volvo, Chrysler, BL Cars, Ford (Germany), AMOCO and Esso (UK).

The study findings, summarized here, are presented in detail in two other separate reports. Of these, the main report (TDC Report No. TP 3976, entitled "A Canadian Dynamic Controlled-Climate Test Facility: Feasibility Study - Final Report", February 1983) contains a full description of the study methodology, analysis, results and recommendations. The supplementary report (TDC Report No. TP 3971, entitled "A Canadian Dynamic Controlled-Climate Test Facility: User Survey Interview Summaries", February 1983) is a separately-bound compilation of the information gathered by DSMA International during the initial user survey phase of the study. It contains detailed results of the prescreening questionnaire, along with summaries of the follow-up interviews which were conducted. Information gained during the questionnaire and interview processes was considered confidential by some respondents and was therefore bound separately in the supplementary report (TP 3971) and made subject to restricted circulation.

SUMMARY

A three-phase feasibility study has been carried out for the creation of a new Canadian dynamic controlled-climate test facility (climatic wind tunnel) for research and development of large vehicles and equipment. The three phases consist of:

1) User Survey
2) Conceptual Design
3) Benefit/Cost Analysis

The user survey solicited interest via Telex questionnaire from 141 Canadian corporations, ten federal government departments, and 22 Canadian universities/colleges, followed by detailed interviews with 30 of the most promising corporate contacts and eight of the government contacts. Significant interest was found in climatic effects with regard to product development, although the Consultants believe that at least 90% of the controlled facility test usage which could be generated by this interest is best served by a large static cold chamber (that is, without airflow simulation). This requirement was met during the study by the announcement of the National Research Council's new Climatic Engineering Facility at the Railway Laboratory near Ottawa (commissioning date in May 1983).

Nevertheless, the user survey has determined considerable interest in dynamic-airflow, controlled-climate testing of large equipment from a limited but important group of corporations, along with research and development concerns on behalf of the the Department of National Defence, the National Research Council, and Transport Canada. Although projected test usage of the proposed facility is low for its first years of existence, the Consultants have identified a strong probability of 'copy-cat' testing coming into play, should the facility be made available. Many potential corporate test clients have climatic concerns, but are unable to articulate or project these into facility usage rates, due to their unfamiliarity with dynamic controlled-climate test concepts and capabilities.

Conceptual designs, with capital acquisition and operating costs, have been developed during the study for three levels of dynamic testing capability. All are proposed on the basis of a phased development of the new NRC Climatic Engineering Facility in order to capitalize on existing test staff and reputation, while sharing site acquisition and development costs.

Capital acquisition costs for the three levels of test capability range from $17.6 million to $20.7 million (estimated to ±20% accuracy in October 1982 Canadian dollars). The highest-capability facility is recommended in order to capture maximum return on investment. Test capability would permit investigations to be carried out on machinery up to and including the size of rail locomotives, for windspeeds of up to 100 km/h and temperatures from +50°C to -30°C. Provision of test temperatures below -30°C is not recommended due to extreme cost penalties for capital construction and operation. Special test systems will permit studies of high humidity, rain and freezing rain, and solar heating, plus chassis dynamometer studies for wheeled vehicles (excluding rail vehicles) of up to 375 kW engine power with a wide range of drive axle arrangements.

The Consultants recommend that the conceptual design elements of this report be used by Transport Canada as the focal point for a new phase of discussions with selected sectors of Canadian industry. By illustrating in definitive fashion a range of proposed testing capabilities, it is expected that considerably greater interest in dynamic controlled-climate testing will be identified amongst Canadian (and United States) corporations. This will in turn lead to a closer definition of facility requirements appropriate to the undertaking of a preliminary engineering phase.

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1. INTRODUCTION

1.1 General

This Summary Report provides an overview of the material treated in detail by the two main reports (References 1 and 2) completed for the Transportation Development Centre (TDC) Controlled-Climate Test Facility study. This report summarizes the study methodology, analysis, results and recommendations described fully in those reports.

The overall study was concerned with the commercial and technical feasibility of a new, Canadian controlled-climate test facility with dynamic airflow simulation for research and development in railway and heavy vehicle/equipment design. The study was conducted in three phases:

a) Survey of potential Canadian users
b) Facility conceptual design
c) Benefit/cost analysis

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1.2 Study Background

In response to interest expressed by Canadian railway operators and vehicle manufacturers for climatic research, TDC initiated the present study of the feasibility of a dynamic (i.e. dynamic airflow simulation) controlled-climate test facility (CCTF). Such a facility would enable improvements to safety, comfort, reliability and performance and would hopefully enhance the competitiveness of Canadian industry in the world railway equipment market.

At the moment, there is no test facility in North America capable of testing complete rail cars or locomotives under dynamic conditions. In fact only one such facility exists worldwide, located in Vienna, Austria at the Vienna Arsenal Vehicle Testing Station. There is a static rail vehicle test facility in Philadelphia owned by the Budd Company (a U.S. rail car manufacturer), but other rail vehicle manufacturers are obviously reluctant to perform sensitive work there.

The Vienna Arsenal dynamic facility was built in 1959-60, upgraded in 1973-74, and is considered essential by European rail operators and manufacturers for their test/development programmes (Ref. 3-9). It has the claimed capability of simulating vehicle aerodynamic for speeds of up to 250 km/h over a broad temperature range. Vienna Arsenal are supported by the International Union of Railways and receive particularly strong support from the German Federal Railway and the French National Railway.

Following a trend by equipment purchasers towards specification of controlled-climate testing in new vehicle purchase contracts, some Canadian rail vehicle manufacturers have expressed interest in the need for a suitable test facility in Canada. This study explores the feasibility of a CCTF within the context of a Railway Advisory Committee research programme.

The Canalog division of CANAC Consultants Ltd. surveyed the Canadian railway sector's climatic test needs as the first phase of this programme (Ref. 10). This survey also included discussions with North American and European railway officials, and visits to the Vienna Arsenal and Budd facilities. The Canadian railway industry displayed cautious interest in a static facility (i.e. without airflow simulation), but little interest in a dynamic facility.

The study at hand constitutes the second phase of the programme. It incorporated a more far-reaching investigation of the need for a dynamic CCTF by surveying a broad spectrum of potential users in both the rail and non-rail heavy equipment manufacturing sectors of Canadian industry. In addition, user interest was solicited from Canadian federal and provincial government agencies, as well as the Canadian university community. Input from this survey has been developed into a conceptual engineering design for a dynamic controlled-climate test facility, followed by a benefit/cost assessment.

2. USER SURVEY

2.1 General Approach

The user survey was designed to try to answer the following question:

> If a large-scale climatic test facility were made available, what use would be made of it by Canadian industry, government and academic institutions?

Following Canalog's experience with their study, it was apparent that objective answers would be hard to obtain due to a general lack of experience in Canadian industry with climatic testing. With this in mind, the present survey attempted to explain the potential capabilities of climatic testing to interviewees whenever possible, with due regard to avoiding bias in the replies by the way in which this information was supplied.

In order to optimize time and cost expenditures, a survey methodology was designed to isolate the most likely users:

1. Organizations which manufacture or operate large mechanical or electrical equipment for outdoor use.
2. Organizations which are concerned about the effects of climatic conditions on their activities or products.
3. Organizations which have an interest in climatic testing and research.

The resulting survey methodology is depicted in Figure 1, and consists of a market classification followed by a series of prescreening questionnaires to establish likely candidates for face-to-face interviews.

Federal government agencies were intensively surveyed, since a significant part of current climatic research and development is supported by government funding. Canadian universities were extensively polled during the prescreening questionnaire phase, since they were felt to represent a second front line in Canadian climatic research activities. The Canadian private manufacturing sector was classified by types and surveyed in appropriately varying depth.

2.2 Canadian Government Agencies

The following federal government agencies were approached directly for face-to-face interviews at the outset of the survey:

National Research Council of Canada (NRC)
- Low Temperature Laboratory
- Railway Laboratory

Department of National Defence
- Land Engineering Test Establishment (LETE)
- Defence and Civil Institute of Environmental Medicine (DCIEM)

Transport Canada
- Motor Vehicle Test Centre, Blainville, Quebec

Energy, Mines and Resources Canada

Environment Canada

Industry, Trade and Commerce

National Energy Board

The detailed results of these interviews appear in Reference 2. NRC and LETE were the most promising respondents, and their comments are summarized below:

2.2.1 NRC Comments

NRC support, two particularly relevant research sections: the Low Temperature Laboratory (LTL), headed by Mr. T. R. Ringer; and the Railway Laboratory at Uplands, headed by Mr. C. A. M. Smith.

The LTL facilities include:

1. Large Static Cold Chamber
2. Low-Speed Icing Tunnel
3. High-Speed Icing Tunnel
4. Outdoor Snow Ingestion Facility
5. Small cold chamber at the Western Laboratory (Vancouver)

A new, static CCTF (to be known as the NRC Climatic Engineering Facility, and now under construction by NRC-LTL at the Railway Laboratory site) will have the following features:

1. Test section dimensions: 30.5 m(L) by 6.1 m(W) by 6.1 m(H)
2. Modularized test section, with independent temperature control
3. Temperature range of -50°C to + 50°C
4. Fully automatic refrigeration system control
5. Concrete floor capable of supporting 270 tonne locomotive
6. Spurline access from mainline railway
7. Estimated cost of $2 Million
8. Commissioning date in May 1983

This new facility demonstrates NRC's commitment to low-temperature research, but is strictly limited to static testing.

During the interview, Mr. Ringer said that most current NRC-LTL work is "mission oriented applied research" for external clients from both the industrial community and the military, and is usually initiated on the basis of external requests. Mr. Ringer felt that a dynamic CCTF would be used at the outset mainly for product development rather than compliance testing, since present compliance standards cater to the types of testing possible with existing, static facilities.

NRC - LTL's work in product development arises from a relatively recent Council-wide Programme for Industry/Laboratory Projects (PILP), which supports the transfer of technology from NRC to Canadian private industry. Nevertheless, the bulk of NRC-LTL's activity lies in research, with progressively lower efforts in performance testing and in product development.

The high profile of NRC-LTL in climatic research and development indicates that a significant proportion of the usage of a dynamic CCTF would involve NRC. NRC-LTL proposed a number of potential applications for a dynamic CCTF, detailed in Reference 1.

NRC-LTL believe that $4,000. would be the maximum feasible daily user fee for a dynamic CCTF, with usage not more than three months per year. Comments by NRC-LTL are detailed in Reference 2.

2.2.2 LETE Comments

The Land Engineering Test Establishment (LETE) are an arm of the Department of National Defence and are primarily concerned with compliance testing and problem solving. LETE have often relied on NRC-LTL for previous climatic testing programmes. LETE's specific testing interests for a CCTF include vehicle cold starting, warm-up and general performance, plus icing and rain studies for land vehicles. Temperatures between -40°C and +40°C would be required.

LETE expressed considerable interest in dynamic CCTF testing for vehicle speeds up to 65 km/h, with a chassis dynamometer accommodating at least four-wheel-drive and perhaps tracked vehicles. LETE indicated, however, that the new NRC-LTL Climatic Engineering Facility (CEF) would fulfill their essential testing needs, with requirements estimated at 20 testing days per year (static/dynamic combined). An Ottawa location with management by NRC-LTL was preferred.

2.3 Canadian Universities

Out of 22 questionnaires mailed to Canadian universities, 14 were returned. Little direct interest was shown in large-scale dynamic controlled-climate research, hence no face to face interviews were conducted. Replies indicated poor understanding of dynamic CCTF testing/research capabilities, and extremely low level of current activity in climatic-related design factors.

2.4 Canadian Industry

The Canadian industrial survey was carried out in three stages:

1. Prescreening Questionnaire - By Telex to 140 Canadian companies. 93 responses (66% response rate).
2. Followup Letter - Where interest and promise were shown, a letter was sent to request and prepare the company for an interview. 46 letters sent.

3. Direct Interview - 30 companies interviewed. The interviewers tried to encourage informed speculation about possible utilization of a dynamic CCTF, while promising restricted circulation of comments. Interview summaries are contained in Reference 2.

Copies of all the relevant forms and letters used during the user survey appear in Appendix II of Reference 1. The interview process was considered productive, although limited by general ignorance of dynamic CCTF research and development capabilities.

2.4.1 Market Overview

Of the 93 respondents to the prescreening questionnaire, 73 were engaged in climatic research and development. The survey results indicate that over 50% of the 140 companies polled (regardless of actual response) are concerned enough about climatic design factors to engage in some degree of related research and development work.

Reference to Table 1 indicates that the greatest level of general response was obtained from the railway, electrical, aerospace and off-highway vehicle sectors. A lower general response rate was noted from the road transport sector.

General observations can be made about the distribution and nature of responses as depicted in Figures 2 through 9.

1. The greatest concern was for the impact of climatic effects on product reliability, performance and design settings. Operator efficiency was secondary.
2. Over 60% of those who indicated concern for climatic effects perform at least small-scale tests in their own facilities.
3. Almost 60% of the respondents rely to some extent on field tests to determine climatic effects.
4. A smaller proportion (35%) make some use of government test facilities.
5. The large majority of positive respondents are located in Southern Ontario and the Montreal/Ottawa region.

2.4.2 Interview Responses

The interviews produced several common concerns and approaches regarding climatic tests:

Technical Considerations

1. Temperature requirements: -40°C to +50°C (extremes were -55°F and +80°C).
2. About 20% of those interviewed were interested in airflow simulation, although almost all were ignorant of dynamic testing implications.
3. Over half of those interviewed expressed interest in simulation of rain, freezing rain, snow, sand or dust; several of these factors require some extent of airflow simulation.
4. Approximately 20% were interested in humidity simulation.
5. Rail access is necessary for the firms in the railway equipment sector.

Commercial and Financial Considerations

1. Several manufacturers were not eager to endorse a dynamic CCTF because of apprehensions that its existence would encourage equipment purchasers to demand related compliance testing. Those manufacturers supportive of the concept were either already committed to relevant testing or anticipating upcoming requirements.
2. Several operating authorities were interested in climatic testing, but wanted their suppliers to perform it.
3. Proximity to the test facility was a governing factor for potential usage.
4. Virtually all the organizations interviewed were extremely cost-conscious.
5. Several firms were noncommittal due to their status as subsidiaries of foreign parents.
6. With the exception of Bombardier, none were committed to using a CCTF for more than thirty days a year, and then only during new product development. They made no guarantee of year-to-year consistency in usage requirements.

2.4.2.1 Bombardier Inc.

On two occasions Bombardier have tested rail cars in the cold chamber of a U.S. competitor, the Budd Company (Philadelphia). The evident drawbacks of this arrangement have contributed to Bombardier's enthusiasm for a Canadian CCTF. They are very positive about climatic testing for a variety of reasons, and equally supportive of the additional dynamic feature. Factors influencing this support include:

1. Performance of climatic tests on prototypes is company policy.

2. In passenger railway vehicles, new materials applications, passenger comfort, and locomotive power consumption are all affected by climate. Utilization of new materials is increasing; insulation design is critical both for passenger comfort and for reliability of subsystems such as water piping; and it is passenger car operating requirements (heating, cooling, and lighting loads), not tractive effort, which currently limit actual train lengths (i.e. number of cars serviced per locomotive).

3. In locomotive development programmes, the following areas require investigation (albeit with lesser priority):

   - Performance consistency under varying climatic conditions
   - Snow ingestion, noise generation by air handling equipment, and location of combustion air inlets

   Some of Bombardier's specific facility design requirements are:
   - easy access for power cables, with large DC power supply
   - data acquisition and reduction system
   - capability of accepting different wheel gauges
   - good thermal insulation
   - solar heat simulation
   - specialist group in charge
   - location in Eastern Canada
   - confidentiality of test results
   - snow and ice simulation (if feasible)
   - availability of support and test personnel

If available, Bombardier would commit to use of the dynamic CCTF for two months annually for the next two years. Future commitments would hinge on the extent of their vehicle development programmes at that time. Bombardier paid the Budd Company $75,000. for each of two three-week static tests conducted there. Bombardier are the single most promising client for a dynamic CCTF.

2.4.2.2 VIA Rail

VIA felt that more research and testing is required in railway vehicle design and operation. Although they see climatic testing as

primarily a supplier responsibility, their limited maintenance capability and restricted rolling stock inventory places a premium on equipment reliability, with consequent incentives to guarantee that reliability. Some of VIA's CCTF design requirements:

1. Good accessibility
2. Reasonable availability
3. Good data reduction capability
4. Acceptable user fees

VIA suggested that a new facility should:

1. Aim to decrease fragmentation of railway equipment testing in Canada
2. Involve an existing organization (preferably NRC)
3. Encourage more testing
4. Be capable of carrying out compliance testing

VIA feel that dynamic testing is crucial to heat-transfer-related passenger vehicle design (heating balance) and are prepared to commit themselves to six weeks of dynamic CCTF testing time per year. There may, however, be some overlap in this projection with that made by Bombardier.

2.5 Summary

2.5.1 Summary of Identified Uses

There were three general categories of ideas for possible testing or research in a CCTF:

1. Specific tests identified by organizations experienced in climatic testing, which require a dynamic facility.
2. Speculative ideas requiring a large-scale facility, although not necessarily a dynamic one.
3. Ideas for research which could be carried out only in a large-scale dynamic CCTF.

The first category includes the requirements of LETE, Bombardier and VIA Rail and forms, along with the more abstract research plans, the basis for the Consultants' proposed facility design.

A. Definitive Requirements

1. Railway Passenger Vehicle Heating Balance Tests (Dynamic)
2. Railway Locomotive Climatic Testing (Dynamic)
3. Military Vehicle Climatic Testing (Dynamic if possible)

B. Speculative Requirements

i) Railway-related testing:

1. Investigations of moisture invasion of traction motors
2. Ore carrier contents freeze-up
3. Durability and performance of railway passenger vehicle or heated vehicle door seals
4. Effects of ever-decreasing fuel quality on low temperature starting of diesel locomotives
5. Effects of ice between brake shoe and wheel
6. Restarting warm engines with cold intake air
7. Fuel tank heater performance
8. Air brake performance during cold weather
9. Snow/ice/dust ingestion by propulsion system cooling blowers
10. Operator comfort systems for locomotive cabs
11. High temperature effects on controls, refrigeration equipment and door actuators
12. Power supply performance for refrigerated cars

ii) Testing of Large, non-Railway Equipment

1. Engine air intake location and filtering
2. Cab heating, ventilation, and air conditioning
3. Air brakeline freeze-up on passenger buses
4. Heater tests in passenger buses
5. Oil circulation in very cold electrical transformers
6. Performance of switchboxes, insulators and air switches in freezing rain, fog and snow
7. Simulation of solar effects on electrical equipment
8. Oil cooler performance for buses

iii) Research Topics

1. Research into enhanced environmental simulation
2. Human factors engineering

2.6 Recommended Facility Design Criteria

The design of the proposed dynamic test facility was influenced by the emergence of committed plans for the new NRC-LTL Climatic Engineering Facility. In addition to satisfying many of the identified potential users for a dynamic facility, the NRC CEF will also provide facility management, experienced test support staff, and geographic placement in accordance with the preferences identified by the user survey.

The proposed design has therefore been configured as a phased development of the new NRC CEF. The proposed dynamic facility would be a closed airflow return circuit, with the test section of the CEF made integral. This would minimize somewhat the capital acquisition cost compared to a completely independent, stand-alone design, while eliminating land purchase costs. The proposed dynamic facility would be managed by NRC and would thus benefit from their experience, reputation, support equipment and technical staff.

3. FACILITY CONCEPTUAL DESIGN

3.1 General

Preliminary design concepts were developed for three increasing levels of dynamic facility test capability. All three concepts focus on the decision of the study Steering Committee and the Consultants that the dynamic facility would be most effectively realized by a phased development of a new Climatic Engineering Facility at the NRC Railway Laboratory in Ottawa (Ref. 11). Conceptual design was based on user needs determined from the user survey, in conjunction with the Consultant's experience and judgment.

Subsequent to preliminary investigations, the Consultants demonstrated that the capital acquisition and operating costs for achieving tunnel airflow speeds of 150 and 200 km/h would be unreasonably high. It was therefore agreed with the Transportation Development Centre during a meeting on April 14, 1982 that a maximum test speed of 100 km/h would be provided for all three dynamic facility configurations (Ref. 12).

Artist's perspectives of the dynamic facility and site layout appear in Figures 10 and 11. Reference drawings of the NRC CEF are included in Appendix IV of Reference 1. NRC-LTL were freely consulted for technical and operational comments throughout the conceptual design phase (Ref. 12, 13, 16-18).

3.2 Facility Location

The location of the proposed Dynamic CCTF is at NRC's Railway Laboratory complex near Uplands Airport (Figure 12), approximately 11 km south of Ottawa's city centre and about 1 km from the Ottawa Airport main terminal. This location satisfies virtually all logistical requirements for the operation of a dynamic CCTF (proximity to rail, air and road transportation routes; proximity to most promising test clients; and availability of support services of all types).

3.3 Overall Arrangement

3.3.1 General

The site plan for the facility is depicted by DSMA Drawing No. E4027-03. The primary elements are:

i) Wind tunnel return circuit
ii) 11.0 m addition to the CEF test section
iii) Support Building No. 1 - administrative/operations control
iv) Support Building No. 2 - refrigeration plant and electrical rooms
v) Support Building No. 3 - air make-up/dehumidification system (Configuration 3 only)

3.3.2 Support Building No. 1

The proposed layout is illustrated in DSMA Drawing No. E4027-04; it consists of a ground floor (94 m^2) plus a full basement.

The layout of the ground floor will be oriented towards contract testing activities for external clients by providing a dedicated office for visiting test staff, a meeting room (which doubles as a staff lounge), and a reception area. Facility staff are provided with two offices, augmenting existing office space in the static facility's support area.

Heated windows will be provided in a new Control Room to permit observation of activities in the new test section addition. The new Control Room will house the dynamic facility's control console and computer, along with desks for test engineers.

3.3.3 Support Building No. 2

Support Building No. 2 contains the dynamic facility's large refrigeration plant, plus the new electrical supply/distribution equipment. Building construction will be prefabricated steel siding applied to a steel structural skeleton. Offices for two stationary engineers will be provided. The building is located along the outside of the air return circuit's fan leg for optimum routing of refrigeration and electrical service connections. Layout and dimensions appear in DSMA Drawing No. E4027-03.

3.3.4 Support Building No. 3

Support Building No. 3 houses the special-purpose air make-up/dehumidification system required in support of vehicle chassis dynamometer testing, and is only provided for Facility Configuration 3. It is a single-storey construction, located within the air return circuit at Corner 1.

3.4 Climatic/Aerodynamic Test Configurations

3.4.1 General

The initial air circuit design required assessing the feasibility of upgrading the NRC CEF to a dynamic capability.

3.4.2 Test Section Design Considerations

The quality of the air flow simulation that can be obtained over a test article is directly related to the size of the test section relative to a given test article. Test article blockage, a critical factor in this regard, is the ratio of the frontal area of the test article to the test section flow area (a maximum of 37.2 m^2 for the NRC CEF test section). Test article aspect ratio (length: height) is also a consideration.

In any wind tunnel design (for climatic or aerodynamic testing), the test section geometry and the nozzle geometry must be carefully matched to the test articles to be studied and to the types of tests to be done. Nozzle configurations are typically either of a closed-jet type (nozzle cross-section area equals test section area) or a semi-open jet type (nozzle area less than test section area). Test section designs fall into two broad categories: the normal solid-wall type, where walls, ceiling and floor have no porosity; and the advanced-concept, slotted-wall type where some of the airflow is diverted through porous walls and ceiling to minimize artificial pressure rises generated by test article blockage.

For the case at hand, the largest test article of interest is a rail locomotive (with frontal areas typically about 14 m^2, for a blockage ratio of 37% in the NRC CEF test section). The resultant pressure rise (for a solid-wall test section) occurring around the front end of such a vehicle is unacceptable for anything but windwipe studies. In the latter case, the extreme length and uniform cross-section characteristic of rail vehicles allows the front-end pressure rise to subside by the time about 15% of the vehicle's length has been travelled. Windwipe investigations would centre around heating balance tests for the heating/air conditioning systems of passenger railcars. It should be noted that for a solid-wall test section, the effective windwipe speeds generated will be much higher than the approach airspeed at the nozzle, since

the annular flow area left between the test vehicle and the test section walls is much less than the nozzle flow area. For the present case, a windwipe speed of about 240 km/h is projected for rail vehicle testing if a nozzle approach speed of 100 km/h is provided. Dummy nosecones and tailcones are recommended for rail vehicle windwipe tests in order to maintain stable and uniform airspeeds over the full vehicle length (see Figure 13a). The solid-wall test section configuration forms the basis for the first of the three facility concepts proposed in this study.

The second proposed facility configuration employs the slotted-wall test section concept (see Figure 13c). The reduced-pressure-rise attributes of this design are mandatory for effective investigations of rail vehicle front end airflow (e.g. cab comfort, air intake placement, etc.) and for tests of medium-blockage, low-aspect-ratio test articles (e.g. military tanks and trucks). The proposed concept (Facility Configuration No. 2) provides slotted walls and ceiling only in the new 11.0 m addition, reverting to a solid wall design over the full length of the NRC CEF test section. Nozzle approach speed will again be 100 km/h, but in this case the flow acceleration over the test vehicle will be minimal.

3.4.3 Nozzle Speed Evaluation

The recommended nozzle dimensions (forced by packaging requirements within the NRC static CCTF test section) are 4.57 m width and 5.33 m height, with a resultant maximum model blockage of about 60% for rail vehicles. Figure 14 illustrates fan power as a function of nozzle speed and its impact on heat exchanger size. It is obvious that 200 km/h is out of the question and that 150 km/h is only attainable with an extremely large heat exchanger (12.2 m square). A nozzle speed of 100 km/h is more reasonable and can still achieve windwipe speeds in excess of 200 km/h.

3.4.4 Tunnel Layout Evaluation

The requirement for controlled-temperature testing dictates a closed-loop air return circuit. In view of the restricted space around the NRC CEF, a vertical return loop was initially proposed (see DSMA Drawing No. E4027-02). Discussions with NRC (Ref. 11) ruled out this configuration, however, due to excessive overall height. The fan leg must be located to the north of the CEF due to NRC plans for a future vehicle fatigue test building to the south.

Installation/removal of major equipment from the CEF will require a mobile crane once the dynamic facility return circuit is in place.

3.5 Airline

3.5.1 General

The proposed airline is shown on DSMA Drawing No. E4027-01. The circuit is 71 m long by 27 m wide. The heat exchanger area is 72.3 m^2 and the fan is 5 m diameter. The contraction ratio (i.e. ratio of nozzle inlet:outlet areas) is 2.4:1. Airflow is directed around each corner by turning vanes, with the vanes assembly at Corner 1 pivoting to permit test vehicle entry (see DSMA Drawing No. E4027-06).

The airline design reflects the optimization of aerodynamic drag, fan power, shell costs, flow quality and refrigeration plant size. Given the available technical data for the comparable Vienna Arsenal Vehicle Testing Station (Ref. 3-9), the predicted flow quality for the proposed airline is at least a three-fold improvement over the Austrian facility.

3.5.2 Test Section Designs

The test section configuration are as follows:

Configuration 1 - full-length solid wall
Configuration 2 - partial-length slotted wall, with convertibility to full-length solid wall
Configuration 3 - as per Configuration 2, but with chassis dynamometer added

Testing capabilities are outlined in Table 2. A discussion of special test support systems appears in Section 3.10. The development from Configuration 1 to 3 is progressive in concept, but not totally amenable to phased acquisition.

a) Configuration 1 (full-length solid wall)

Dimensions of the solid-wall test section are identical to those of the nozzle exit (5.33 m high and 4.57 m wide). This will necessitate a removable "sleeve" in the static test section to

create the correct cross-section. The removable liner will consist of three matched sections. Removal/installation will require a railway flatcar fitted with special-purpose hydraulic jacking frames.

b) Configuration 2 (partial-length slotted wall)

The proposed design concept is illustrated in DSMA Drawings No. E4027-06 and E4027-07. A permanent, slotted-wall test section is provided over the full length of the 11.0 m addition. The inside cross-section measurements (i.e. height and width between slats) match those of the nozzle exit cross-section. The outside cross-section of the annular plenum matches that of the NRC CEF test section (i.e. 6.1 m height and 6.1 m width).

Re-entry flaps located in the plenum at the end of the slotted-wall test section permit the fine-tuning of plenum airflow such that windwipe velocity along the length of the test vehicle can be set approximately equal to nozzle velocity. For longer test vehicles, these flaps are augmented by a second set at the downstream end of the solid-wall liner. Regardless of test vehicle length, the front of the test vehicle will always be positioned at the upstream end of the 11.0 m addition.

The solid-wall liner need be in place only for rail vehicle windwipe tests, during which time the slotted-wall section would be made solid-walled by manual closure of the hinged filler pieces (see "End View", DSMA Drawing No. E4027-07).

c) Configuration 3

This configuration is the same as Configuration 2, but with the addition of a chassis dynamometer in the floor of the 11.0 m addition for testing of wheeled road vehicles.

3.6 Shell, Insulation and Foundations

3.6.1 General

The proposed return circuit shell is shown in DSMA Drawing No. E4027-05. The majority of the shell (from the first crossleg to the

nozzle inclusive) will be of steel, while the new test section leg segments will be a concrete outer structure with a sandwich-type refrigeration panel inner liner. The existing NCR CEF test section will be integrated essentially unchanged.

3.6.2 Shell Material Selection

The steel shell will be a continuous, welded-steel structure with thermal expansion joints only at the interfaces with the concrete shell. The fan housing segment will be rigidly anchored, while all other foundation points will provide compliance for thermally-induced movements.

The structure of the new test section addition and the first corner will consist of a structural steel skeleton with concrete block walls, a conventional roof, and an insulated concrete floor. The air circuit will be defined within this structure by an inner shell of refrigeration panels, supported off the structural steel. Rail track will be provided from the Corner 1 door to the halfway point of the 11.0 m test section addition. Floor drains will be provided over the full length of the test section.

3.6.3 Shell Insulation and Cladding

The steel shell sections will be insulated by an external covering of porous-skinned fibreglass. The insulation layer will be protected by light-gauge, pre-painted, corrugated steel cladding.

In the concrete shell, insulation will consist of the aforementioned, pre-painted refrigeration panels (steel-insulation-steel sandwich). All doors and openings will be insulated and sealed at the edges.

3.7 Fan and Drive

The fan and drive system is comprised by the rotor, blades, nacelle, stator blades, plus the motor and drive (with associated lubrication and cooling systems). The preliminary scheme includes a custom-designed axial fan with adjustable-pitch blades of 5.0 m diameter and hub-to-tip diameter ratio of 0.5:1. Variable-pitch inlet guide vanes may be necessary. The fan drive will be a variablespeed DC motor, nacelle-mounted within the air circuit and featuring SCR (thyristor) speed control.

The drive will be designed strictly for steady-state operation in order to limit power requirements. A speed turndown ratio capability of 10:1 will be provided.

Shaft power requirements are as follows:

a) high-blockage, solid-wall - 2.28 MW
b) high-blockage, slotted-wall - 2.06 MW
c) low-blockage, slotted-wall - 1.97 MW

3.8 Cooling/Heating System

3.8.1 General Design Requirements

The cooling/heating system regulates tunnel air temperature by the removal or addition of heat. This will be carried out by a main, air-to-liquid heat exchanger mounted across the entry to Corner 3 in the fan leg. The required capacity of the cooling/heating system is a function of the minimum working temperature, the temperature range, the required rate of temperature change, and the cooling load on the system. These will have first-order impact on facility acquisition cost and on the Plant Room size. The design of the cooling system is governed by:

a) small air-to-brine temperature differences to ensure temperature uniformity over the flow cross-section
b) wide range of temperatures and loads
c) acceptable temperature pulldown times
d) ease of operation and maintenance

Operation will be fully automatic (plant engineers are, nevertheless, presently required by law), except for manual emergency overrides.

3.8.2 Proposed System Elements

a) Compressors

Constant-speed, multiple-stage, screw-type compressors are recommended. This type of compressor has been used successfully on seven of the Consultants' climatic test facility designs.

b) Main Heat Exchanger

The heat exchanger will have multiple rows of plate-fin arrangements with a surface area ratio of 10 to 15:1. Air/brine temperature difference will be held to about about 10°C.

c) Brine/Refrigerant

For the minimum temperature requirement at hand, the recommended brine and refrigerant are trichloroethylene and a fluorinated hydrocarbon respectively.

3.8.3 Cooling System Operation

DSMA Drawing No. E4027-08 shows a schematic flow diagram for the cooling system. The system consists of cooling water, refrigerant, brine and air circuits (plus the optional make-up air system for Facility Configuration 3). A detailed explanation of the system operation appears in Reference 1, but is not considered appropriate for inclusion here. The brine circuit is provided with an electrical heater to assist natural tunnel heating (i.e. fan kinetic energy) during high-temperature testing.

3.8.4 System Performance and Sizing

In order to limit ccoling system size, the system is sized strictly for steady-state testing for temperatures ranging from -30°C to +50°C. Preliminary estimates of cooling requirements are:

Configuration 1: 2.64 MW
Configuration 2: 2.64 MW
Configuration 3: 3.14 MW

Four compressors will be required for Configurations 1 or 2, and 6 compressors for Configuration 3. Under worst-case ambient conditions (outside temperature +32°C, high humidity), it will take an absolute minimum of six hours to pull tunnel air temperature down to -30°C. It is therefore recommended that the smaller refrigeration plant (200 kW) of the NRC CEF be used to sustain tunnel air temperature at about -5°C during an overnight hold. The large CCTF plant would be reactivated in the morning for a final 2 to 3 hour pulldown to -30°C. The CCTF main fan would remain in low-speed operation overnight to maintain air circulation.

3.8.5 Options for Reduced Operating Temperatures

The implications of operating down to -40°C and -50°C during worst-case ambient conditions are as follows:

ITEM	-40°C	-50°C
No. of Compressors	8	14
Capacity Increase Factor	1.5	2.5
Plant Room Size Increase Factor	1.3	2.0
Pulldown Time (minimum)	8 hr.	12 hr.
Acquisition Cost Increase (minimum)	$2 M	$6 M

Further implications include increases in staff requirements, use of exotic materials, plus increases in insulation requirements, fan power and electric consumption.

3.8.6 Vienna Arsenal Vehicle Testing Station Dynamic Facility Performance

The proposed facility airflow quality and temperature range represent significant improvements over that offered by the Austrian dynamic facility. The Consultants' investigations of the Vienna Arsenal dynamic facility performance claims indicate that testing at maximum air speed in that facility cannot be carried out at minimum temperature due to inadequate cooling capacity. A complete discussion of the Austrian facility's performance capabilities is given in Reference 1.

3.9 Control and Data Acquisition (Facility Support System)

3.9.1 General

The Facility Support System has two main functions:

1. Dynamic Facility Control
2. Data Acquisition for dynamic testing

A schematic is shown in Figure 15. Since testing in the dynamic facility will be only for steady-state temperature/windspeed conditions, it will not be necessary to provide a sophisticated interface between the control and data acquisition functions. The proposed computer configurations are based on making full use of the system already available at the NRC CEF.

3.9.2 Control Functions

The Dynamic Facility Control System (DFCS) will support the following basic functions:

1. Control Parameters

   i) Windspeed
   ii) Air Temperature
   iii) Humidity
   iv) Dynamometer (Configuration 3 only)
   v) Make-up Air Control (Configuration 3 only)
   vi) Test Engine Exhaust Extraction (Configuration 3 only)
   vii) Re-entry Flap Control (Configurations 2 and 3 only)
   viii) Purge System (Configuration 3 only)
   ix) Solar Simulation (Configurations 2 and 3 only)
   x) Rain Simulation (Configurations 2 and 3 only)
   xi) Freezing Rain Simulation (Configurations 2 and 3 only)

2. Facility Safety Interlocks

   i) Fan Interlocks - The main fan will be appropriately interlocked with the CEF test section end doors, the new Corner 1 door, and the purge fan.

   ii) Heat Exchanger Interlocks - The main heat exchanger and make-up air heat exchangers (optional) will be interlocked with the fan, dampers, and the refrigeration system.

   iii) Emergency Pushbutton - When the emergency pushbutton is activated, all control functions will abort to a safe state.

3. Operator Interfaces

   i) Tunnel Status - Displays air temperature, coolant temperature, heat exchanger outlet temperature, dew point, steam grid temperature, dynamic pressure, total pressure, fan speed, and all other system variables.

ii) Control Status - Displays control modes, process variables, targets set-point values, controller outputs and update rate for all of the control loops.

iii) Loop Parameters - Displays and allows modification of control loop parameters (gain, reset time, filter break-points, break-point ratios) for all control loops.

iv) System Commands - Involves direct communication with the system executive for start/stop control, power-up/down, and system backup.

3.9.3 Data Acquisition Functions

The Data Acquisition System (DAS) will provide primary support for the collection of sensor signals (thermocouples, pressure taps, etc.) from the test article. The number of signals to be scanned and the scanning rate will depend on the specific test or experiment. The DAS is configured for easy modification in this regard, anticipating a high degree of variability in experiment types. This is realized through "pseudo-channel" assignment, sensor library, and auto-calibration features. The DAS proposed incorporates user-friendly data acquisition software, with report generation and data management capabilities.

3.9.4 Hardware Configuration

The control system computer configuration is shown in Figure 16. The basic control system will consist of an ADAC 1000 (LSI 11/23), along with a power supply, card cage, backplane, and 9 cards (see Reference 1 for full details).

For mass storage the system will have a Winchester disc (5.2 Mb) with a floppy disc (512 kb). Operator interface will be through two VT100 terminals. An LA-38 hard-copy terminal will be used for logging. The signals used for control will include the following:

i) Dynamic pressures (wind speed)
ii) Static pressure
iii) Motor speed (fan speed)
iv) Tunnel air temperature
v) Tunnel and test article surface temperatures

vi) Brine temperatures
vii) Heat exchanger(s) outlet temperature(s)
viii) Dynamometer speed/load (optional)
ix) Make-up air temperature (optional)
x) Auto/manual status
xi) Support equipment status
xii) CEF control equipment status

The output from the control computer will typically consist of the following:

i) Fan speed set-point
ii) Heat Exchanger(s) mixing valves' position set-points
iii) Steam valve position set-point
iv) Rain and freezing rain control set-points
v) CEF equipment control interface
vi) Re-entry dampers' position set-points (with slotted walls)
vii) Dynamometer speed/torque set-point)
viii) Make-up air damper position set-points)
ix) Defrosting heater set-points) optional
x) Purge system damper position set-points)
xi) Engine exhaust extraction fan set-point)

3.9.5 Data Acquisition System Configuration

The Data Acquisition and Display Computer will be based on the existing HP-3054 system in the NRC CEF. This system consists of the following new equipment:

i) HP 9845B desk top computer with 187 kb memory
ii) HP 3497 Data Acquisition and Control Unit
iii) HP 3456A Digital Voltmeter
iv) One 16-channel Digital Input card
v) One 16-channel Digital Output card
vi) Relay multiplexers

If further expansion is required, it can be done by using an HP 3498A expansion box together with the appropriate I/O module assemblies.

3.9.6 Safety Systems

In addition to the safety interlocks integral to the facility subsystems, the DFCS will incorporate a facility-wide safety programme. The occurrence of an unsafe condition or the existence of an interlocked condition will be displayed on the operator's console and the appropriate action will be taken automatically by the DFCS.

Three separate gas analyzers will be supplied to monitor ambient levels of CO, hydrocarbons and trichloroethylene in the return circuit and the Plant Room. High levels of hydrocarbons will cause main fan shut-down, plus both visual and audible alarms in the Control Rooms.

3.10 Special Test Systems

3.10.1 Humidity Control System

The humidity control system is a common feature of all three configurations. It is composed of a steam grid in the second crossleg and a steam generator in the Plant Room. The steam system will be sized for 900 kg/h (600 kW) output and will be controlled by the Facility Support System. The steam system will be capable of creating relative humidities of up to 10°C depressed dew point temperature (relative to tunnel air ambient) for tunnel temperatures above 0°C. Progressively degraded performance will occur for temperatures lower than this.

High-humidity investigations include carburetor icing, sensitivity of electrical systems, and cab comfort evaluations. Medical research activities will be concerned with the cumulative effect of temperature, humidity and windspeed on personnel efficiency and comfort levels.

3.10.2 Rain and Freezing Rain Simulation

In order to enable rain simulation for cab leakage, traction motor infiltration, and windshield wiper tests, a single-nozzle, pressurized water system with manual positioning will be provided in Facility Configurations 2 and 3. A pump and a 20,000 ℓ storage tank will be supplied.

For freezing rain, the options are for 'global' or localized sources. The 'global' approach consists of a 5 m x 5 m spray rake with 40 atomizer nozzles in a heated manifold. Distilled water would be pumped at up to 100 ℓ/min and mixed with pressurized air at the nozzles. This water/air/stream system would cost more than $250,000. including the associated compressor, supply lines and controls, and would create significant problems in the remainder of the air circuit design. Reference 19 documents existing specialized icing tunnels, two of which are Ottawa-based NRC installations and suggest an unwarranted redundancy. Therefore, a local-source approach is recommended, using existing NRC equipment.

This equipment consists of portable 1.5 m spray rakes of concentric-circle/radial-spoke configuration. Operating principle is similar to the 'global' system but with reduced supply rates. The local-source system will include a 10 kW compressor, a distilled water supply tank, pump and filters. During an icing test, the portable spray rakes will be manually positioned for spray application to the zone of interest on the test article.

3.10.3 Solar Simulation System

At the present time, the best simulation of solar heating is provided by a compact-source-iodide lamp, typically rated at 1 kW per unit. The proposed system provides for 200 of these lamps flush-mounted in the slotted-wall liner in the new test section (see DSMA Drawings No. E4027-06 and E4027-07). The installed cost of these lamps (including associated wiring, transformers and controls) is more than $1,300. per unit; hence, the illuminated area (at 1.0 kW/m^2 intensity) will be limited to 7.0 m by 3.5 m.

A forced-air cooling system will be required along the length of the slats involved. Power will be supplied by 8 "Regavolt" variable-output transformers to control lamp intensity from 60% to 100% of maximum.

3.10.4 Dynamometer System

The chassis dynamometer provided in Facility Configuration 3 will be for highway and off-highway vehicles, but not rail vehicles. Since the facility fan drive and cooling system are only designed for steady-state testing, the cost penalty for direct current or

eddy-current dynamometers cannot be justified. A hydrokinetic dynamometer is recommended as being most cost-effective for the testing programmes envisaged.

The assembly proposed is a Clayton-AESI Model HCT 200/400/200 with three separate roll-pairs, each with its own absorber unit and inertia flywheel system. It would accommodate one, two and three-axle drive. A separate, removable dynamometer rig could perhaps be provided for tracked vehicles. The rolls assemblies will be adjustable for various wheelbases and recessed into a pit such that the test vehicle will sit at floor level when positioned on the rolls.

The absorber units for the leading, central and trailing rolls assemblies are rated at 150, 300 and 150 kW respectively. Each unit is capable of independent control and has its own speed/load control and read-out. The load/speed curve for the 150 kW absorber is shown in Figure 17. Each roll assembly is rated at 1134 kg axle load and can simulate up to 1815 kg vehicle inertia.

3.10.5 Combustion Air Make-up/Dehumidification System

During dynamometer testing, tunnel air consumed by the vehicle engine must be replaced with dehumidified fresh air. To contend with ice formation in the dehumidifying system, two separate and parallel units will be required, with one operating while the other defrosts. The air make-up system will be housed in Support Building 3, and is shown schematically on DSMA Drawing No. E4027-08. A full description of the operating principles appears in Reference 1.

3.10.6 Engine Exhaust Extraction System

The purpose of the extraction system is to prevent engine exhaust gases from fouling the tunnel air, as well as loading the tunnel cooling system. An insulated flexible pipe will provide the connection from the vehicle exhaust pipe to the facility exhaust manifold. A variable-speed fan will draw outside air, mix it with the engine exhaust and then blow the mixture outside. Pressure sensors at the vehicle exhaust pipe and within the test section will permit the Facility Support System to control the fan speed in such a fashion as to minimize engine backpressure.

3.10.7 Tunnel Purge System

The tunnel air purge system is part of the facility's Safety System (see Section 3.9), and is appropriate to Facility Configuration 3 only. The purpose of this system will be to provide emergency purge ventilation of the air circuit in the event of a fuel spill. The system will consist of three explosion-proof exhaust fans drawing contaminated air through floor level ducts in the test section. A fourth fan will ventilate the dynamometer pit. Actuation of the system will be triggered by a gas detection unit or by a manual command from either of the control rooms. This will also shut down the main fan drive and the test vehicle engine.

3.11 Electrical Power Supply and Distribution

3.11.1 Distribution

The basic electrical distribution scheme is illustrated in DSMA Drawing No. E4027-09. The main substation located east of Support Building 2 (see DSMA Drawing No. E4027-03) will step down the main supply from 27.6 kv to 4.16 kv. Capacity will be 7,500 kva for Facility Configurations 1 and 2, or 10,000 kva for Configuration 3. The fan drive will be supplied with variable DC power by a dedicated converter.

3.11.2 Supply

Preliminary estimates of the maximum total loads on the grid are:

Facility Configuration 1: 6.63 MW
Facility Configuration 2: 6.63 MW
Facility Configuration 3: 6.92 MW

Recommendations for the supply source (either Ontario Hydro or Gloucester Hydro) and projections on its actual availability are necessarily tentative at this time. Current supply to the NRC Railway Laboratory is far below the above requirements, so a new main feeder line is essential. Given the massive draw and projected usage patterns (intermittent, relatively short duration, and short-term advance notice), Gloucester Hydro's representative indicated that the facility would constitute a less-than-desirable customer. It must be assumed at this stage that the full cost of the required

line upgrade will have to be absorbed within the facility acquisition cost (Reference 24). A very approximate estimate of $250,000. has been made to upgrade the existing NRC 8.32 kv line to the recommended 27.6 kv.

3.12 Site Integration

The following is a list of the required site work:

a) Site Clearance and Preparation: Clearing of 1000 m^2 of treed area and moderate amount of cut and fill to establish level ground.
b) Access and Parking: A new 7000 m^2 parking lot north of Building U-89 and a new service road as shown in DSMA Drawing No. E4027-03.
c) Sewage: Relocation of existing leaching field 20 m north of its present location.
d) Water Supply: Filling of existing well and creation of new well east of the complex. Supply line extensions.
e) Rail Spur Re-Alignment: Relocation of final curve in the existing rail spur.
f) NRC CEF Condenser Pad Relocation: Demolition of existing pad, placement of new pad, relocation of condenser, and extension of piping.
g) Main Substation Transformer Pad: Concrete support pad with gravelled site and fence, east of Support Building 2.
h) Site Drainage: New east-west culvert, extension of existing culvert to meet new culvert, and new manhole and culvert to drain new service road.
i) Electrical Supply/Distribution: Upgrading of existing 8.32 kv feeder or installation of new 27.6 kv supply from the Hawthorne Road Substation (Gloucester Hydro).
j) Miscellaneous:
   - relocation of existing 80 m perimeter fence
   - 30 m of new perimeter fencing
   - shell lightning protection
   - general internal lighting for the CCTF
   - general outdoor lighting for roadways, parking lot and buildings

4. PROPOSED FACILITY PERFORMANCE

The appearance of a single value for an item indicates that the same performance will be achieved for all three facility configurations.

4.1 Airflow

a) Maximum Speed (measured at nozzle exit plane, -30°C)

No. 1. 90 km/h (windwipe speed: 145 to 225 km/h, depending on blockage)

No. 2. 100 km/h (windwipe testing available)

No. 3. 100 km/h (windwipe testing available)

b) Flow Quality

No. 1. Windwipe testing only for rail vehicles. Full climatic study capability for test articles with less than 30% blockage

No. 2 and 3. Full climatic study capability for test articles of up to 60% blockage. Windwipe testing also available.

c) Airline Specifications

Nozzle Area:	23.4 m^2
Contractions Ratio:	2.4:1
Test Section Height:	5.33 m
Test Section Width:	4.57 m

d) Fan Specifications

Diameter:	5.0 m
Maximum Speed:	540 rpm
Turndown Ratio:	10:1
Speed Control:	±1.0% of full scale
Power:	2.28 MW
Drive:	DC-SCR

4.2 Temperature and Humidity

Test Temperature:	-30°C to +50°C (±1°C)
Pulldown Time:	6 hrs (ambient to -30°C)
Maximum Dew Point Depression:	-10°C (relative to tunnel ambient)

Refrigeration Plant Size:

No. 1	2.64 MW
No. 2	2.64 MW
No. 3	3.14 MW

4.3 Dynamometer (Facility Configuration 3 only)

Maximum Speed:	195 km/h (nominal)
Maximum Absorbing Power:	150 + 300 + 150 kW
Absorber Type:	Hydrokinetic
Inertia Simulation:	Flywheels, 1815 kg/roll max.
Maximum Axle Load:	11340 kg/axle
Operating Modes:	Constant-speed or constant-torque
Vehicles:	Up to three-axle drive; no tracked vehicles

4.4 Special Test Systems

See Table 2 and Section 3.10

5. OPERATING CONSIDERATIONS

The operation of the dynamic facility will almost certainly be an intermittent activity during the first few years of operation. Since the dynamic facility and the NRC CEF will share the same test section, any staff totally dedicated to the operation of one facility will benefit the other. Due to the special functions of the dynamic facility, however, it will place additional demands on the resources of the operating organization.

5.1 Test Sequence

The test process in a large dynamic facility involves a large number of steps. In general, the scale of the tests carried out in a dynamic facility will place a complex demand on the supporting organization. The major steps involved in the test sequence will include at least the following:

1. Test Specification - Potential clients may ask for assistance from the test facility operator in defining the test objectives.

2. Test Setup - Preparation and instrumentation of large test articles is often the most labour-intensive task in fixed-facility climatic testing.

3. Temperature Pulldown - In a test facility of the size and mass proposed here, it may take 6 hours or more to stabilize the shell and air mass at the minimum testing temperature. This will have major impacts on the staffing and operational requirements of the facility.

4. Testing Programme - The test programme content will vary tremendously over the different test types. Optimum operating procedures will have to be worked out in light of actual testing experience.

5. Test Cleanup - This is a corollary of Test Setup.

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6. Data Reduction and Report Generation - Data analysis requirements will vary greatly among tests. The test facility operator would be expected to provide the resources and staff for much of the data reduction.

5.2 Summary

The operating procedures of the dynamic test facility will evolve over the first few years of operation. Since the ultimate testing mix is unknown, it would be a futile exercise to try to optimize operating procedures at this preliminary stage. What is virtually certain, however, is that the testing procedures will be subject to a substantial learning curve. For those test regimes which are repetitive, testing should become more and more efficient with time. This is relevant to operating cost estimates, since productivity should increase substantially as the staff becomes more knowledgeable about the facility's operation.

6. COST ESTIMATES

6.1 Facility Acquisition Cost Summary

Budget cost estimates have been developed for the three dynamic facility configurations described in Section 3. These cost estimates are broken down initially into six broad categories, as follows:

1. Site Preparation and Services
2. Support Buildings
3. Wind Tunnel Hardware
4. Electrical Power Supply/Distribution
5. Architectural Services
6. Engineering, Programme Management, and Constructor Charges

For Categories 1-4, costs have been developed wherever possible using the unit cost data obtained from References 20-22. In the case of specialized hardware (eg. wind tunnel shell, test support systems, etc.), costs have been developed on the basis of the Consultant's in-house expertise and reference data developed from comparable installations in other facilities. In special cases (e.g. the chassis dynamometer for Configuration No. 3), preliminary quotations were obtained from suppliers. For Categories 1-4, cost elements are broken out in some detail in Reference 1, to provide a better understanding of the make-up of the final totals.

The fees developed for architectural services are calculated as a percentage of the total combined costs for site preparation and services, plus support buildings. The percentage used (15%) is considered representative of typical practise for the type of installations under consideration.

Under Category 6, engineering fees include all engineering costs associated with hardware and systems design, procurement, installation and commissioning. Programme management and constructor charges include total programme management during design, construction and commissioning of the complete facility. Programme management would involve planning and scheduling, project budgeting and cost control, procurement, construction management and supervision. Constructor charges are comprised of overhead, warranty, financing, guarantees, insurance and margin. All of the above charges in Category 6 are calculated as a percentage of the facility hardware

and electrical power distribution costs developed in Categories 3 and 4 (excluding the 27.6 kv power supply cost).

All of the costs developed in this section are in Canadian dollars, with a time reference of October, 1982. No attempt has been made to incorporate an escalation allowance on the basis of a projected acquisition schedule. Costs include subcontractors' overheads and profits, but do not include taxes or duties. Land costs are similarly excluded. The final facility cost estimates represent the cost for acquiring the Dynamic Controlled Climate Test Facility with -30°C capability at the NRC Railway/Laboratory site on a turnkey design-and- supply basis. The costs for the three configurations are considered accurate to within ±20% accuracy.

ITEM	CONFIGURATION NO. 1	COST NO. 2	(x $1,000) NO. 3
1. Site Preparation and Services	205.4	206.0	211.0
2. Support Buildings	291.0	291.0	329.5
3. Wind Tunnel Hardware	9,086.0	9,663.7	10,792.2
4. Electrical Power Supply/ Distribution	1,047.0	1,072.0	1,167.0
5. Architectural Fees	74.5	74.6	81.1
6. Engineering, Programme Management, and Constructor Charges	6,890.2	7,511.7	8,151.0
TOTAL -	17,594.1	18,819.0	20,731.8

6.2 Lower Operating Temperature Options

As a supplement to the acquisition costs presented in Section 6.1 above for the -30°C operating temperature baseline, investigations have also been carried out for the case of -40°C and -50°C temperature capabilities. The technical implications of these enhanced performances have already been discussed in Section 3.8. Briefly, they involve considerable increases in cooling system performance and hardware, plus commensurate upgrading/expansion of the new Plant Room, the electrical supply (including main and unit substations), the relevant electrical distribution system elements, plus the control and safety systems. The approximate increases in facility

acquisition cost over those given in Section 6.1 are as follows:

-40°C	add $2 MILLION
-50°C	add $6 MILLION

7. COST/BENEFIT EVALUATION

7.1 Basic Assumption of Cost/Benefit Analysis

Attempting to estimate the cost/benefit tradeoffs with any testing or research oriented investment is difficult at best. This is particularly the case with the unique facility proposed in this study. In addition to the problems of defining benefits, there are some methodological problems which must be overcome.

The most important question centres on the relationship between the dynamic facility and the almost-completed NRC CEF. The analysis in this report treats both costs and revenues for the proposed dynamic facility as "incremental" to those of the CEF. In other words, only the costs incurred specifically for the dynamic facility are considered. Similarly, only the testing revenue and benefits over and above those normally expected of the CEF are accounted for. These costs and benefits are summarized as follows:

1. Incremental Capital - All of the construction costs of the dynamic facility are clearly incremental and are included in the cost estimate.

2. Incremental Fixed Labour Costs - The dynamic facility will require between 5 and 15 permanent staff to provide technical and operational support for the facility. Since these staff members will likely have no other duties, their full costs must be considered.

3. Variable Labour Costs - A small amount of variable labour costs will be incurred by the dynamic facility, but the bulk of the labour costs will be fixed.

4. Material Cost - The most significant material cost will be for the extra hydro capacity needed to run the fan and refrigeration units in the dynamic facility. Over 80% of this cost will be essentially fixed as a peak load charge. In total, the hydro costs will likely represent at least 50% of the total annual operating costs. By comparison, the other materials costs for incremental consumables will be variable in nature and insignificant in scale.

5. Incremental Testing Fees - Since all of the costs associated with the dynamic facility are incremental, the same criteria must apply to any testing revenue generated through user fees. The only revenue credited to the dynamic facility is that over and above the fees charged by the CEF. Given the responses received during the user survey from the industrial community, these incremental fees are unlikely to exceed $1,000. to $3,000. per testing day.

6. Incremental Benefits - This category deserves special discussion, primarily because the incremental benefits have proven so difficult to estimate. Most of the obvious benefits which would accrue from climatic simulation will be achieved with the NRC CEF, yet a select group of potential industrial test clients have been identified whose test requirements can only be met by a dynamic CCTF.

These considerations form the basis of the cashflow analysis which was performed as part of the study. Several scenarios were examined and the results of two of the more realistic scenarios are shown in Tables 3 and 4. These scenarios are constructed according to the general rules defined above. The specific assumptions, however, are given in the following sections.

7.2 Capital Cost

The capital cost of the dynamic facility will be between $17.5 million and $20.7 million, depending on the level of test capability. When the effect of variations in demand on the level of operating costs is taken into account, it appears that a 10% increase in the present value of the investment would at least double the potential utilization of the dynamic facility. Accordingly, the conclusion of the study at this point is that the most versatile facility configuration should be the basis for overall evaluation.

7.3 Operating Costs

The first scenario is a conservative estimate of both costs and revenues. In other words, this scenario tends to inflate costs and downplay revenues. It represents the Consultants' best estimate of capital and operating costs as they can now be predicted. There are, however, a number of cost items which may be amenable to further reduction.

In the Consultants' experience, skilled test facility management is usually very resourceful in squeezing the most out of the testing dollar. NRC have proven particularly adept at this in the past and it is reasonable to expect them to continue this practice. Accordingly, the second scenario incorporates more optimistic estimates of operating cost and, even though it is not entirely justified by current conditions, it may be the most likely. This scenario also includes explicit consideration of substantial research activity over and above industry-sponsored testing.

7.4 Incremental Testing Revenue

Throughout the discussions with industrial organizations, it was evident that their demand would be extremely cost-sensitive. While industry representatives were reluctant to make firm statements regarding appropriate testing fees, it was apparent that demand would largely disappear if the incremental testing fees exceeded $1,000. to $3,000. per testing day.

7.5 Cost/Revenue Summary

It is apparent from the cashflow scenarios that the likely incremental testing fees are entirely inadequate to support the dynamic facility's operation. Even if the fees were several times greater, their impact would not be significant. The dynamic facility must therefore be justified on the basis of its ability to contribute to the general welfare of Canadian society.

7.6 Social Benefits

Assessing the social benefits of any testing or research-oriented investment is difficult at best. This is certainly the case with

the dynamic CCTF under consideration. The reasons for these difficulties can be summarized as follows:

1. The organizations contacted in the user survey were characterized by a lack of familiarity with the potential uses and value of a dynamic controlled-climate test facility.

2. With few exceptions, the organizations contacted were unwilling or unable to speculate about their potential usage of the dynamic facility for either contract testing or developmental research.

3. Although the organizations contacted suggested a number of possible test requirements which might utilize a dynamic test facility, the scope of these requirements was usually very specific to the company involved. The Consultants did not find test requirements which could be generalized on an industry-wide or economy-wide basis.

Taken together, these problems make the numerical estimation of social benefits a very difficult proposition. At the same time, the response obtained during the user survey in no way precludes the existence of social benefits. The Consultants found no indication that Canadian industrial and institutional research organizations would not support such a facility. Most organizations were at least mildly interested in the capabilities of a dynamic facility, even if they could not foresee how they might use one.

The attitude of the organizations contacted is not surprising given the nature of the dynamic facility. The relevant benefits are those which are realized through the facility's unique testing capabilities. Large equipment manufacturers and operators have never had occasion to even consider fixed-facility dynamic testing. Until they have had an opportunity to digest the concepts presented to them in this study, it seems improbable that informed and considered comment will be forthcoming. By the same token, these same organizations have expressed a strong concern for climatic effects on their products and services. Given a chance to consider the extensive testing capabilities available in a dynamic facility, they may generate entirely novel test requirements.

The significant exceptions to the above generalization lie among the passenger rail car manufacturers and operators, notably Bombardier Inc. and VIA Rail. Both of these organizations expressed strong interest in a dynamic facility and related it quite strongly to the success of rail passenger car exports and Canadian rail passenger travel.

7.7 Summary

The dynamic test facility will cost between $18 million and $22 million to build, plus additional operating costs over its operational life. Several of its capabilities would be unique both in North America and worldwide, and would open new possibilities for fixed-facility climatic testing of large-scale outdoor equipment. These capabilities have particular relevance to the rail passenger vehicle industry and to a lesser extent to the military vehicle industry.

In addition, the facility would offer unique opportunities for institutional research in large-scale climatic testing. The scope of such testing and research will, however, only be defined when Canadian industry and research institutions have had a chance to give more thought to the possibilities. A greater degree of discussion and description of the proposed facility and its capabilities than was possible within the scope of this study will be required in order to quantify the potential benefits.

8. SUMMARY AND RECOMMENDATIONS

8.1 Summary

A three-phase feasibility study has been completed with regards to the design, acquisiton, and potential utilization of a new Dynamic Controlled-Climate Test Facility (climatic wind tunnel) in Canada. Primary elements of the study were:

1) User Survey
2) Conceptual Design
3) Benefit/Cost Analysis

A. User Survey

The first phase of the study solicited interest in controlled climatic testing via questionnaire format from 140 Canadian corporations, ten Canadian federal government agencies, and 22 Canadian universities and colleges. Contacts with prospective test clients in the United States were excluded from the terms of reference for the study. Detailed follow-up interviews were carried out with the 30 most promising industrial contacts and eight of the government contacts. Highlights of the survey results were as follows:

i) Industry response to the prescreening questionnaire exceeded 66%.

ii) Almost 90% of the industrial respondents to the question naire indicated that their products were subject to design constraints and/or operational problems as a consequence of exposure to adverse or varied climatic conditions.

iii) There are no Canadian test facilities (industrial or government-owned) in existence with the capability for testing large vehicles/equipment under dynamic, controlled-climate conditions.

iv) 90% of the controlled-climate testing need identified by the survey can be adequately met by a static facility (i.e. static hot/cold room), assuming a comparable range of temperature capability.

v) There is minimal current interest amongst Canadian university/college researchers in dynamic controlled-climate testing of large vehicles/equipment.

vi) Relatively strong interest in dynamic controlled-climate testing of large test items exists amongst the following Canadian federal government agencies:

- Department of National Defence
  a) Defence and Civil Institute of Environmental Medicine
  b) Land Engineering Test Establishment (DND)

- National Research Council of Canada
  a) Low Temperature Laboratory
  b) Railway Laboratory

- Transport Canada
  a) Transportation Development Centre

vii) Strong interest in dynamic controlled-climate testing of large equipment was expressed by a limited but important group of corporate contacts, notably within the inter-city and urban rail transportation sectors (both manufacturing and operations).

viii) More than 90% of the most promising candidates for dynamic controlled-climate testing of large equipment are located within southern Ontario and Quebec.

B. Facility Conceptual Design

Design of a facility suitable for meeting the requirements for dynamic testing identified by the User Survey is quite feasible. Conceptual designs for such a facility have been carried out, concentrating on three levels of increasing test capability. For reasons of cost and projected utilization, all of the conceptual designs are configured as phased developments of the National Research Council's new static Climatic Engineering Facility, located at the Railway Laboratory near Uplands Airport, Ottawa. Although this 'add-on' strategy results in relatively minor savings with regards to dynamic facility hardware

costs, important economies are realized in operating costs, land acquisition and site preparation. Noteworthy aspects of the proposed designs are as follows:

i) The dynamic facility will consist of the addition of a large, ground-level, closed-loop air return circuit and two new support buildings.

ii) Integration within the existing NRC site and buildings can be accomplished without significant detriment to any on-going activities or existing structures.

iii) Capital acquisition and operating costs make it inadvisable to provide for basic airspeeds in excess of 100 km/h and minimum test temperatures below -30°C. Windwipe tests for long rail vehicles will be possible for airspeeds in excess of 200 km/h.

iv) The recommended facility will offer the following special test capabilities:

- humidity control
- solar simulation
- rain/freezing rain simulation
- chassis dynamometer testing of wheeled (non-rail) vehicles for drive configurations up to 6x6 and road power outputs up to 375 kW

v) Snow simulation and chassis dynamometer testing of tracked vehicles are feasible, but will require separate and costly development programmes.

vi) Supply of electrical power for the facility will require extensive planning and negotiations with the local utility.

vii) Temperature pulldown performance of the proposed facility will be a critical element with regards to staffing requirements and facility productivity.

C. Benefit/Cost Analysis

Capital acquisition costs for the three facility configurations will range from $17.6 million to $20.7 million (estimated to ±20% accuracy in October 1982 Canadian dollars), depending on level of testing capability. In view of the relatively small incremental cost for acquisition of the highest-capability configuration, it is recommended that the two lower-level configurations be eliminated.

Results of the User Survey Study suggest an initial maximum utilization for the dynamic facility of 30 testing days annually, rising progressively to 90 days after 10 years. An intermediate cashflow analysis based on these figures predicts an operating subsidy requirement of $35,000. per testing day for the facility.

The Consultants believe that utilization predictions for the facility are understated. In almost all of the follow-up discussions held with prospective test clients, representatives of the company/agency were essentially ignorant of dynamic, controlled-climate, fixed-facility testing in terms of capabilities, precedents, costs, availability and benefits. The Consultants believe that if the proposed facility is implemented and successfully used by one or two high-profile corporate clients, 'copy-cat' testing on the part of competitors or comparable-application manufacturers may generate sigificant increases in utilization. There is, of course, a 'chicken and egg' element to this argument, and the degree of risk is obvious given the projected cost estimates for acquiring the facility.

The Consultants also believe that the potential testing load stemming from pure research activities may easily double that projected for design/development applications in the dynamic facility. It is unlikely, however, that research programmes requiring such a class of facility will be defined by the sponsoring agencies/corporations until after the facility is made available.

8.2 Recommendations

The Consultants have determined low to moderate Canadian interest in fixed-facility, controlled-climate testing of large equipment under dynamic airflow conditions. A limited number of high-profile testing clients have been identified as being very interested in dynamic controlled-climate testing. Financial risk in terms of acquisition and operating costs for a suitable facility are considered quite high, given current projections of utilization. There is no indication, however, that a dynamic controlled-climate test facility of the class under consideration would be built independently by any Canadian industrial concern, particularly within the next five years.

Realization of a climatic wind tunnel class of facility is considered technically feasible, but is recommended only as a phased development of the existing Climatic Engineering Facility at the National Research Council's Railway Laboratory.

It is the overall recommendation of this study that Transport Canada initiate a programme of discussions with a selected group of prospective testing clients within the Canadian (and perhaps United States) industrial community. These discussions should focus on the conceptual design segment of this report in an attempt to familiarize the companies with potential applications and benefits to be derived from a defined facility configuration and capability. The potential for entering the preliminary engineering and detail design phases for the dynamic facility should be judged on the basis of utilization proposals and guarantees derived from these discussions.

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FIGURES

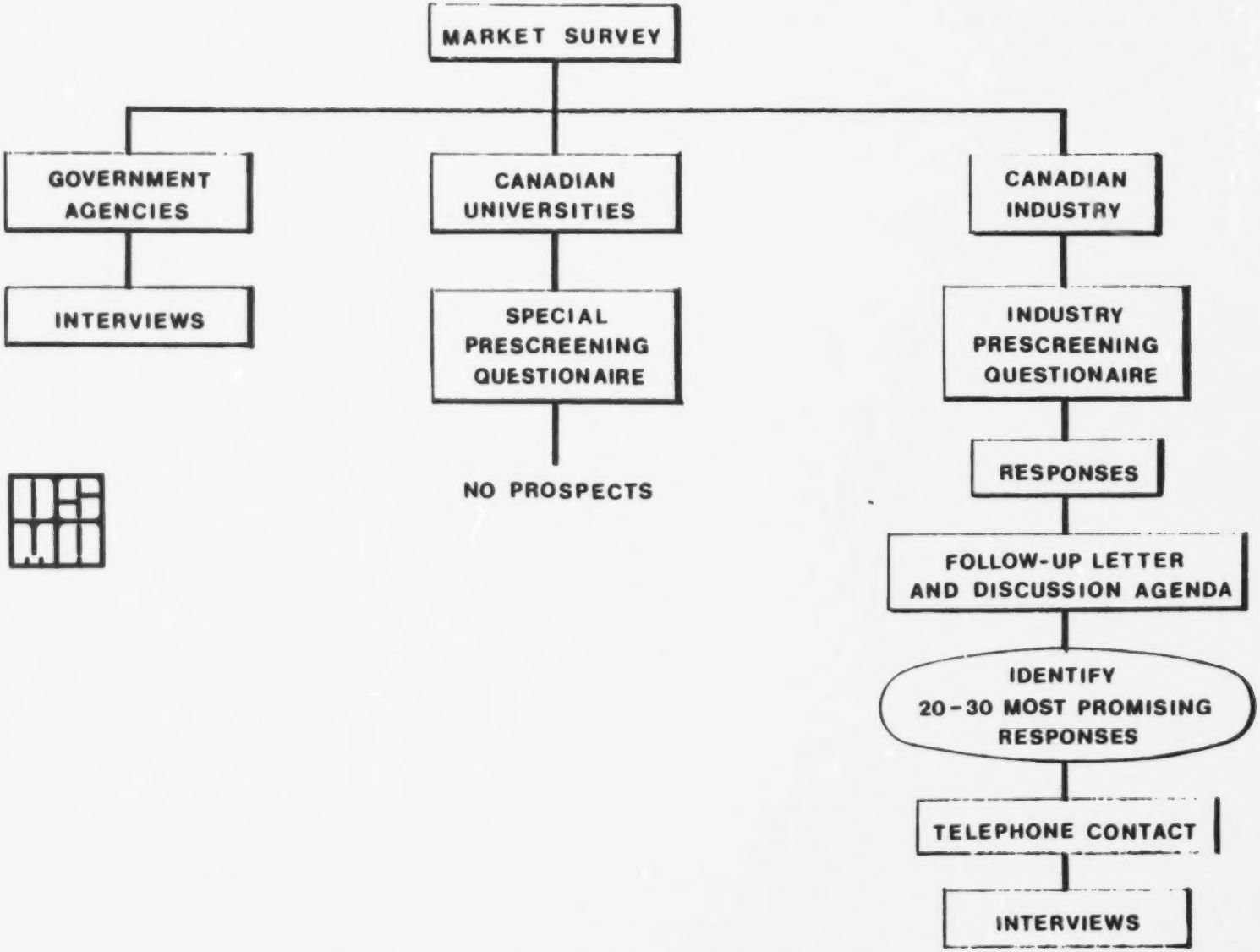


Figure 1. USER SURVEY - METHODOLOGY

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Road Transportation Vehicles

Level of Response : 16 of 32

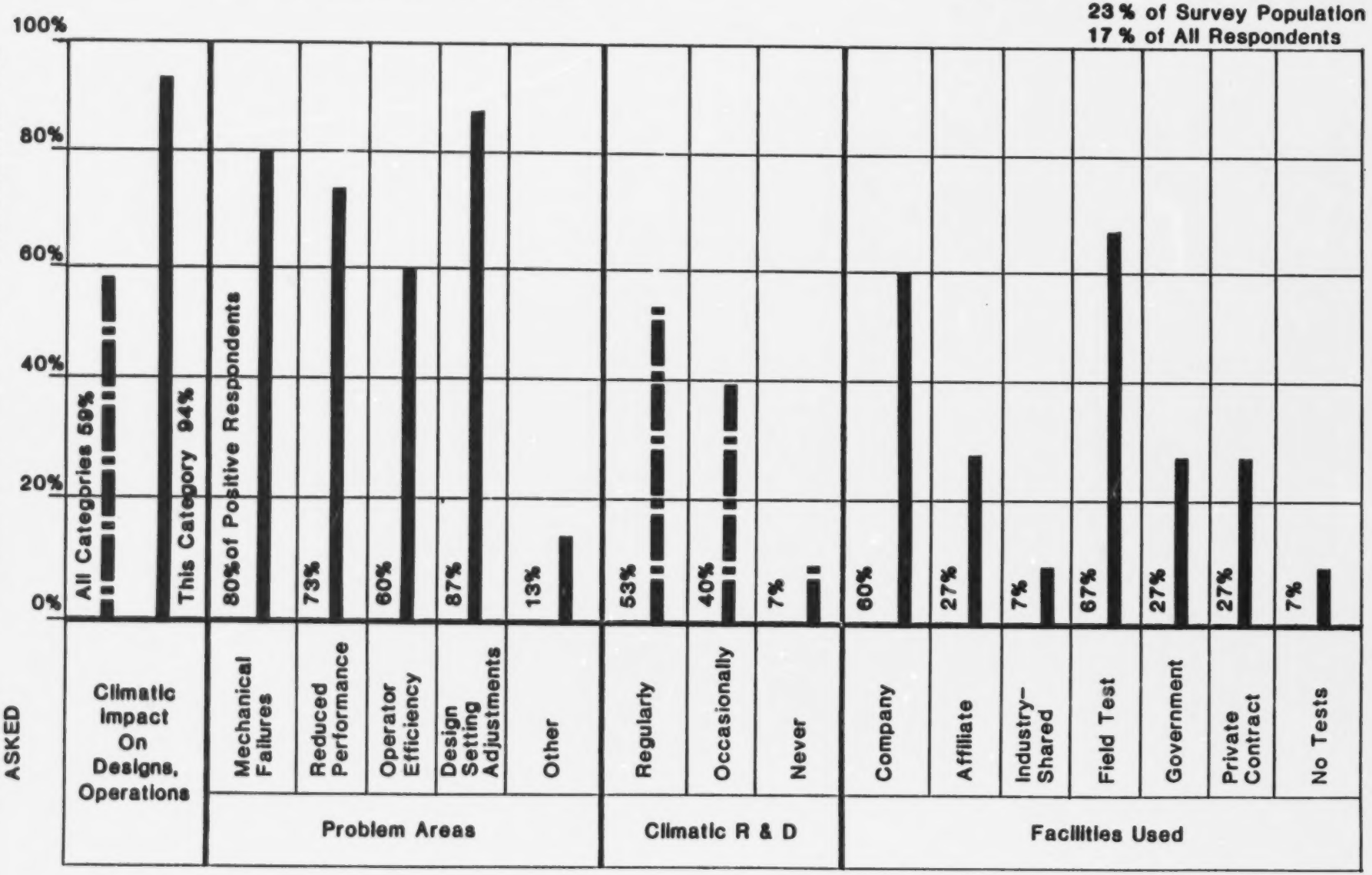


Figure 2

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Off-Highway Vehicles

Level of Response : 29 of 38

27 % of Survey Population
31 % of All Respondents

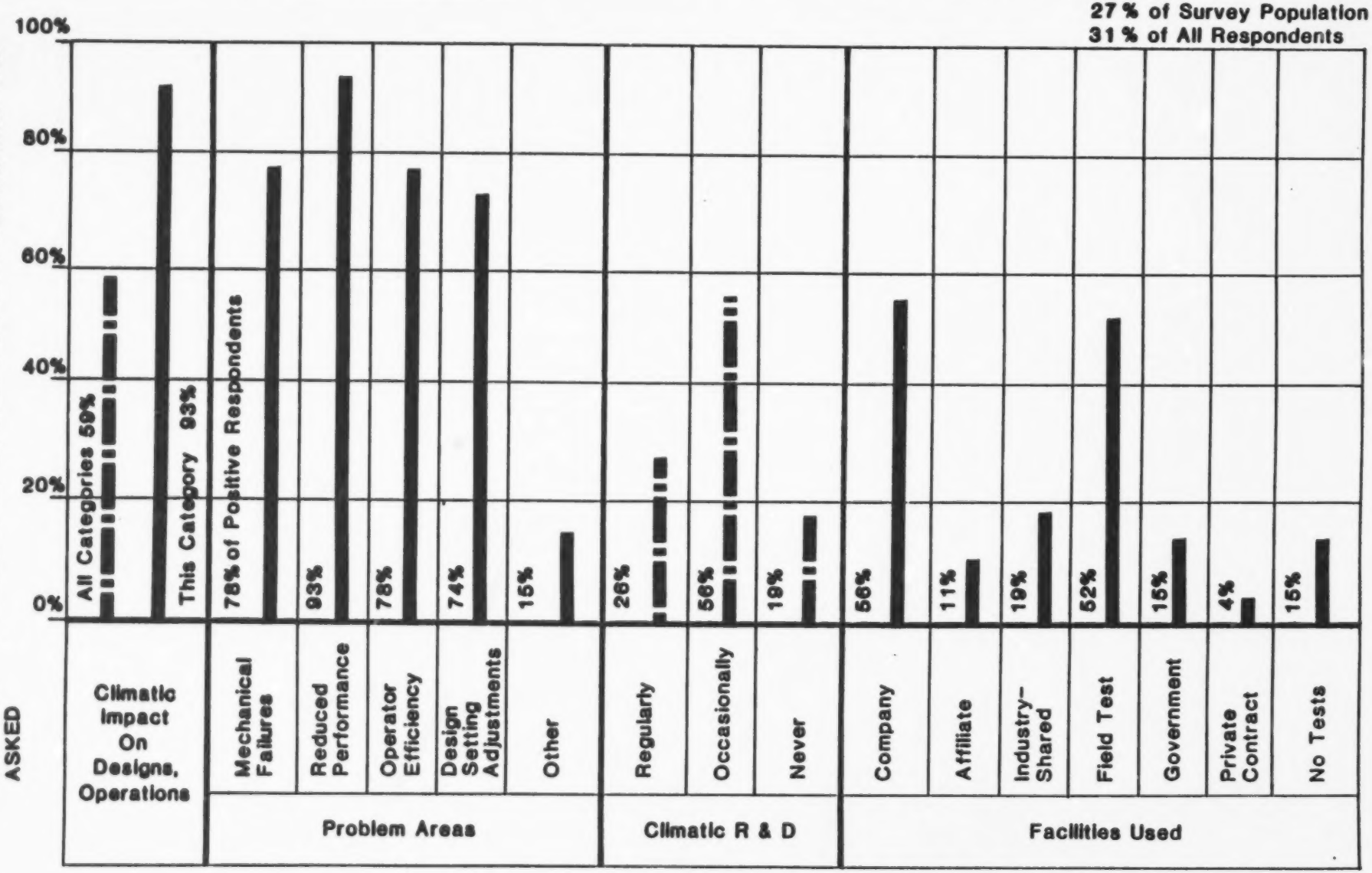


Figure 3

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Inter-City and Urban Rail

Level of Response : 12 of 12

9 % of Survey Population
13 % of All Respondents

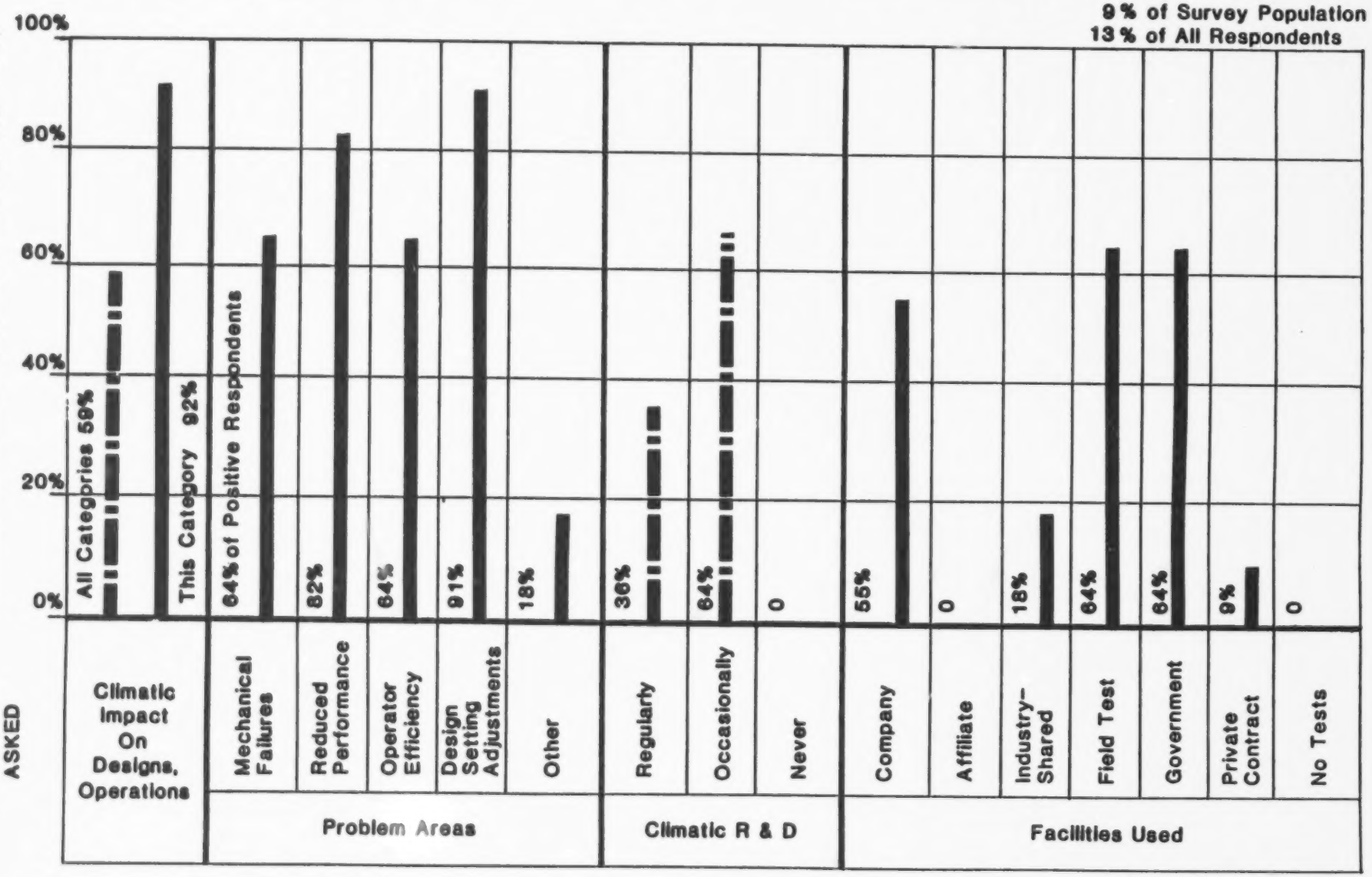


Figure 4

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Aerospace and Support Equipment

Level of Response : 10 of 12

9 % of Survey Population
11% of All Respondents

Figure 5

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Petroleum, Mining and Materials Handling

Level of Response : 12 of 23

16 % of Survey Population
13 % of All Respondents

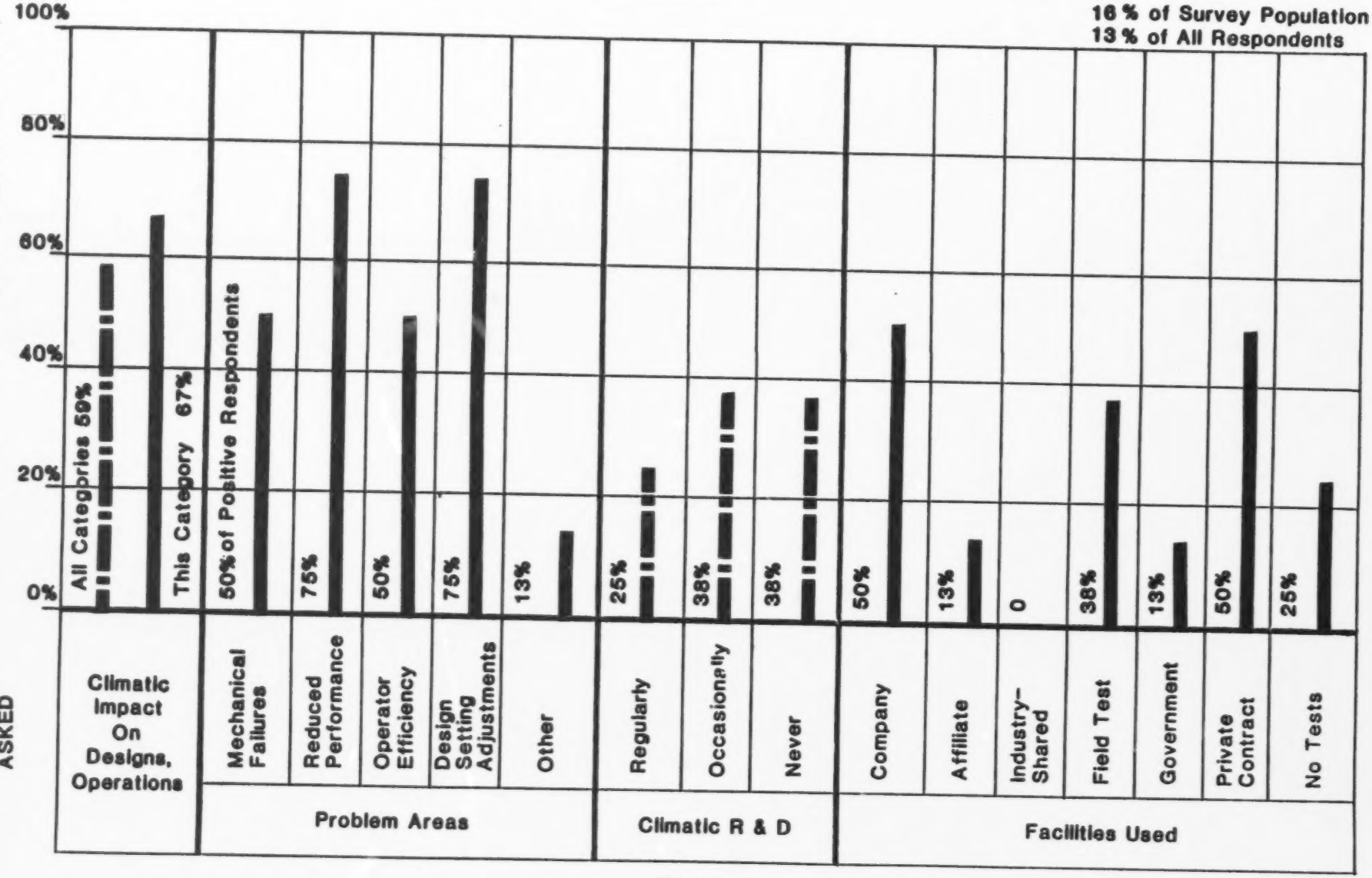


Figure 6

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Marine Equipment

Level of Response : 4 of 8

6 % of Survey Population
4 % of All Respondents

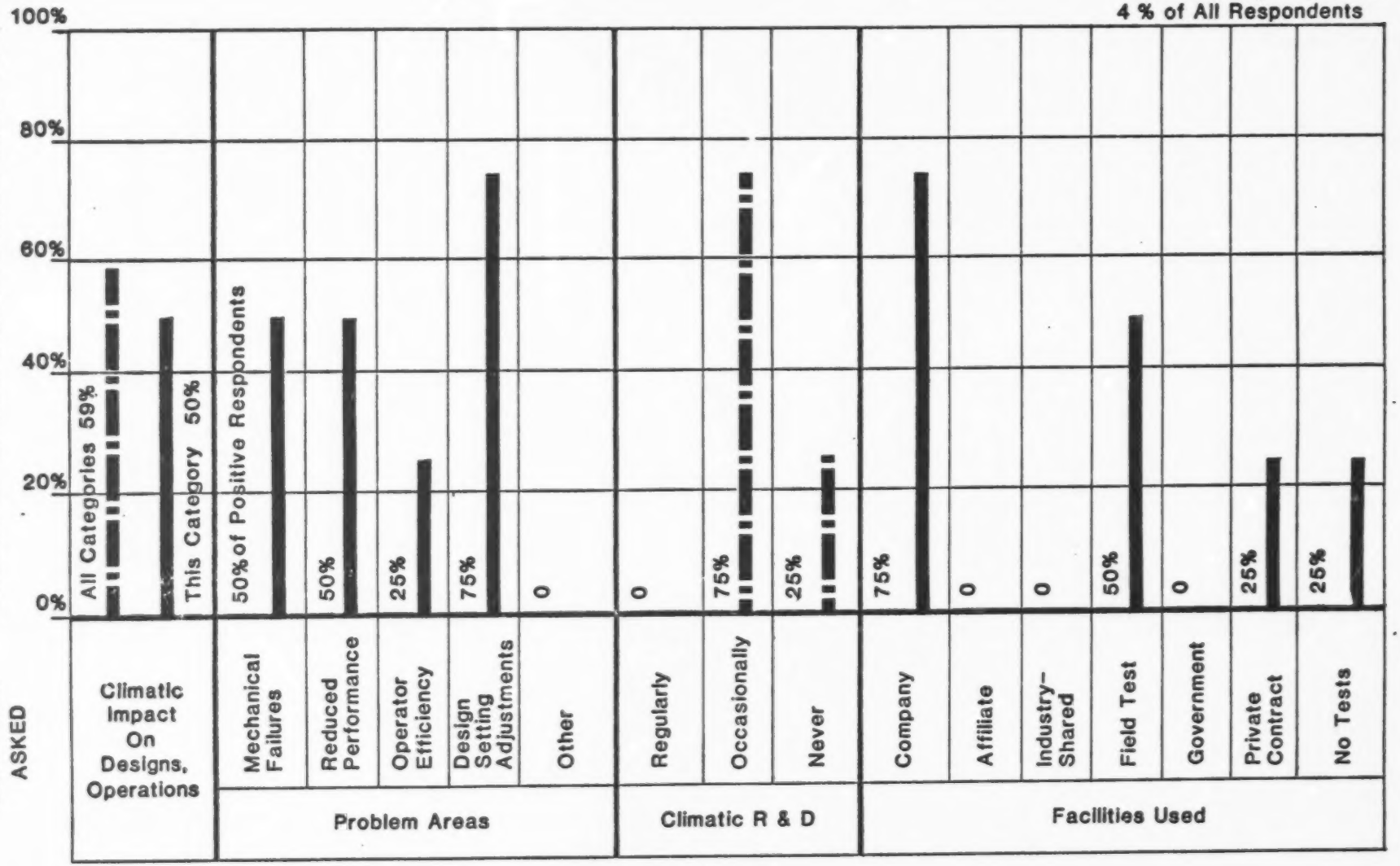


Figure 7

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Electrical Equipment and Services

Level of Response : 9 of 11

8 % of Survey Population
10 % of All Respondents

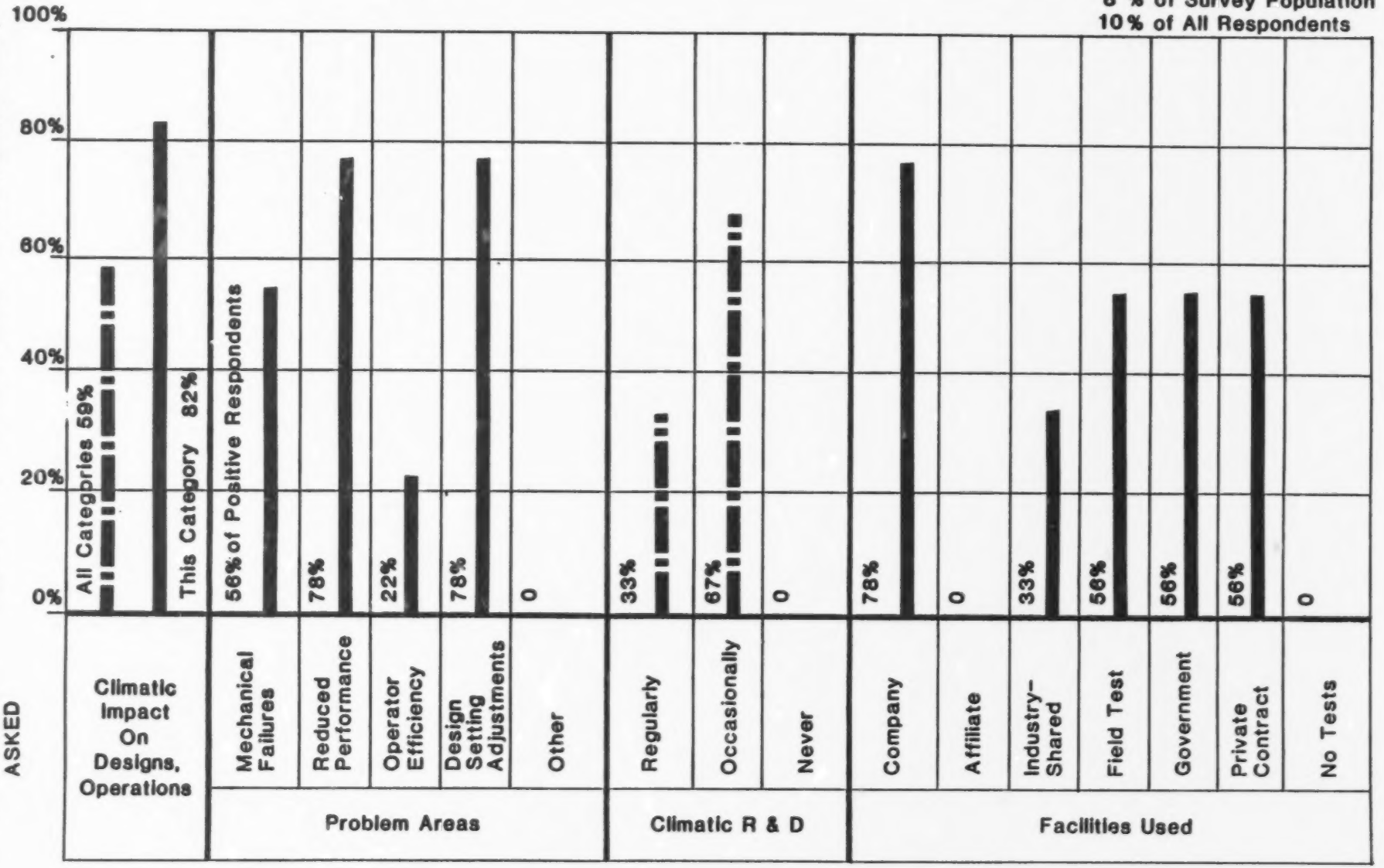


Figure 8

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY
USER SURVEY - PRESCREENING QUESTIONAIRE RESULTS

LEVEL OF RESPONSE BY GEOGRAPHIC REGION

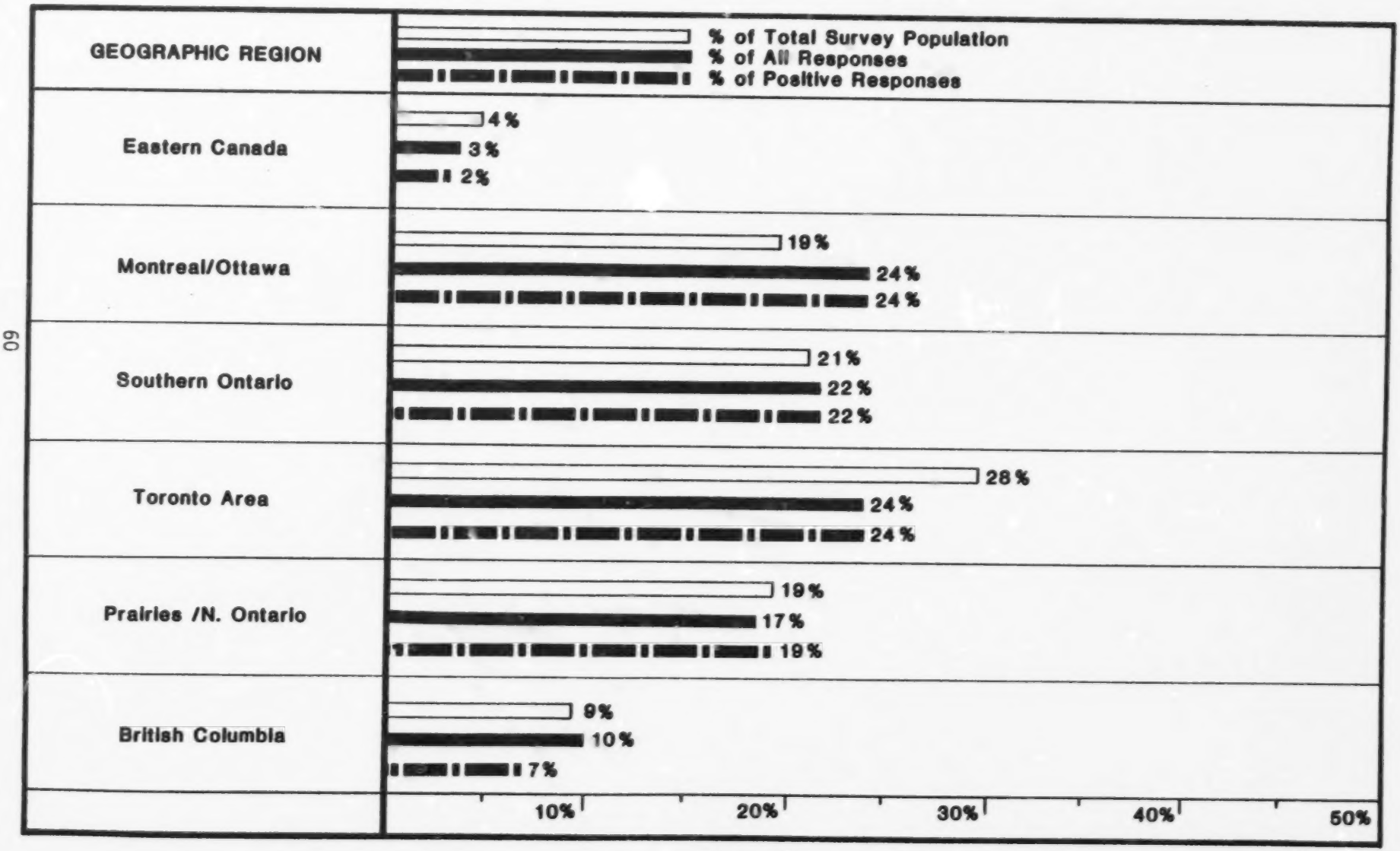


Figure 9

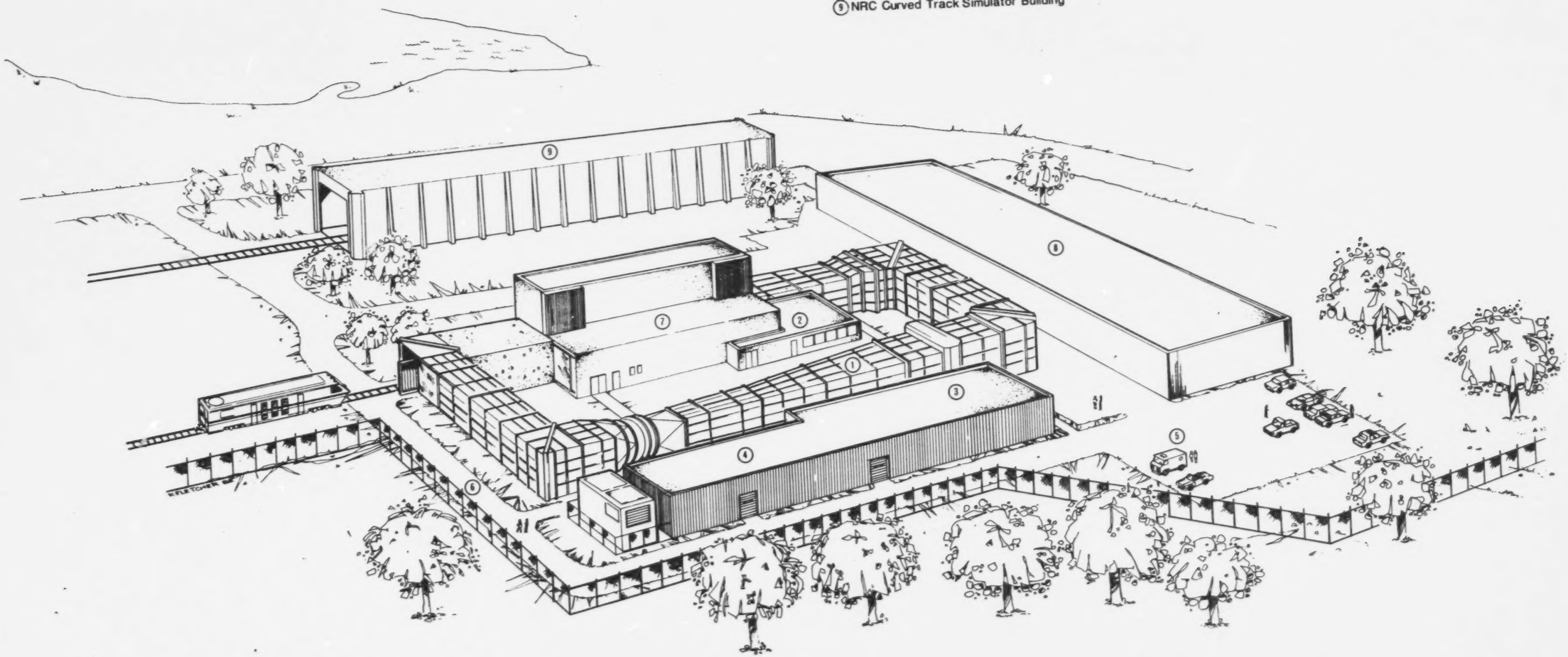

1 Dynamic Test Facility Return Loop
2 New Support Building
3 New Plant Room
4 New Electrical Room
5 New Parking Lot
6 New Access Road
7 NRC Static Test Facility Building U-88
8 NRC Building U-89
9 NRC Curved Track Simulator Building

Figure 10. Transport Canada Dynamic Controlled-Climate Test Facility:
Site Drawing for the Phased Development of
the NRC Climatic Engineering Facility

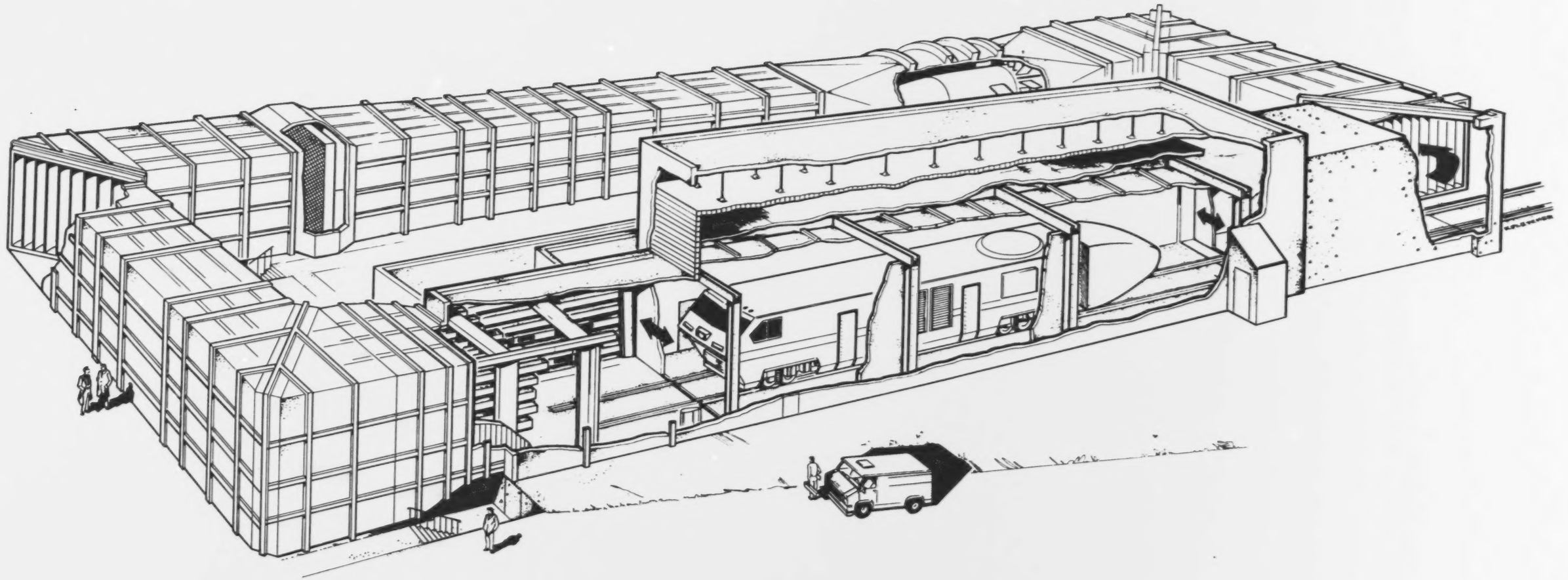


Figure 11. Transport Canada Dynamic Controlled – Climate Test Facility:
Tunnel Shell Configuration for Phased Development of
the NRC Climatic Engineering Facility

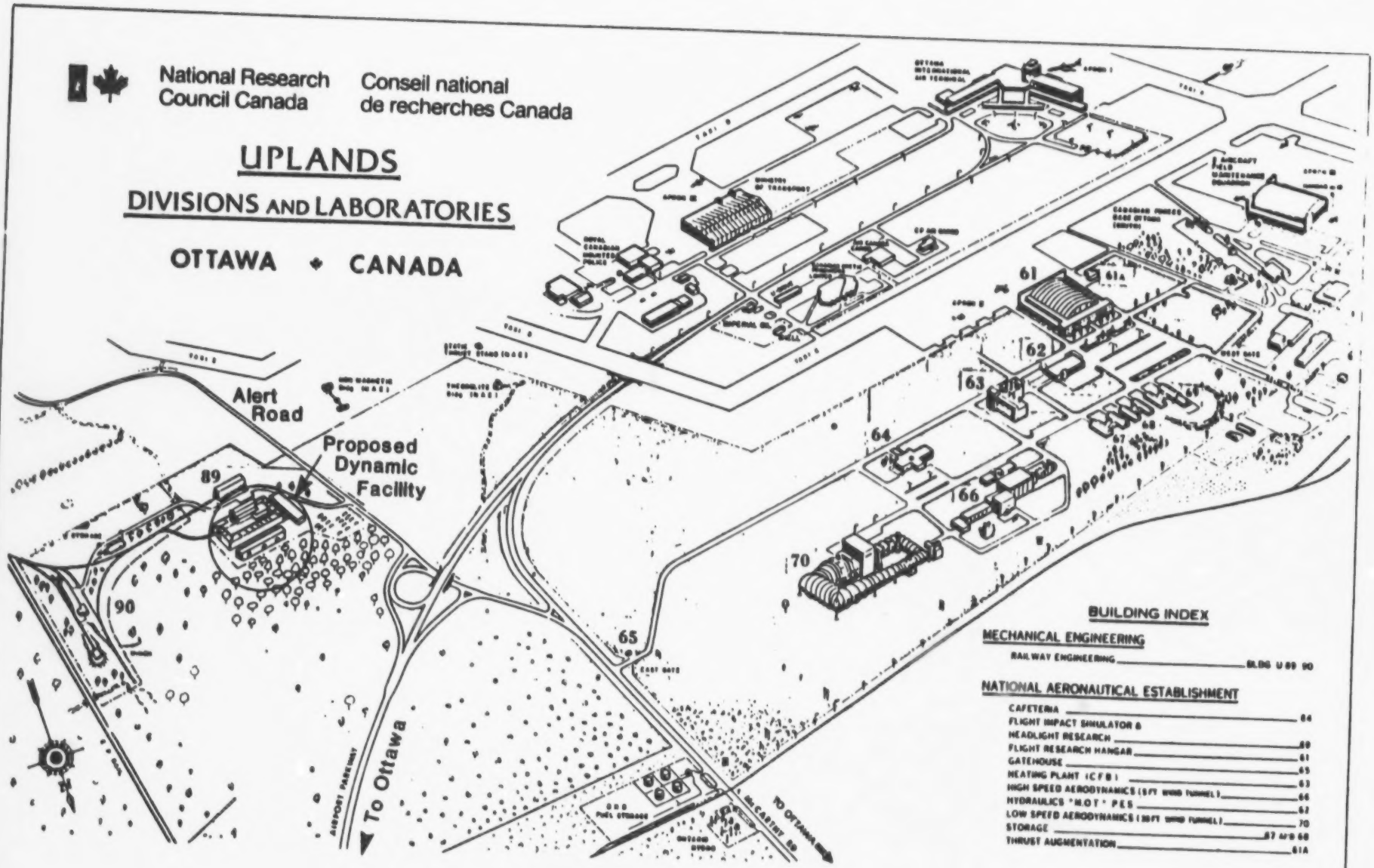


Figure12 Proposed Uplands Location and Environs

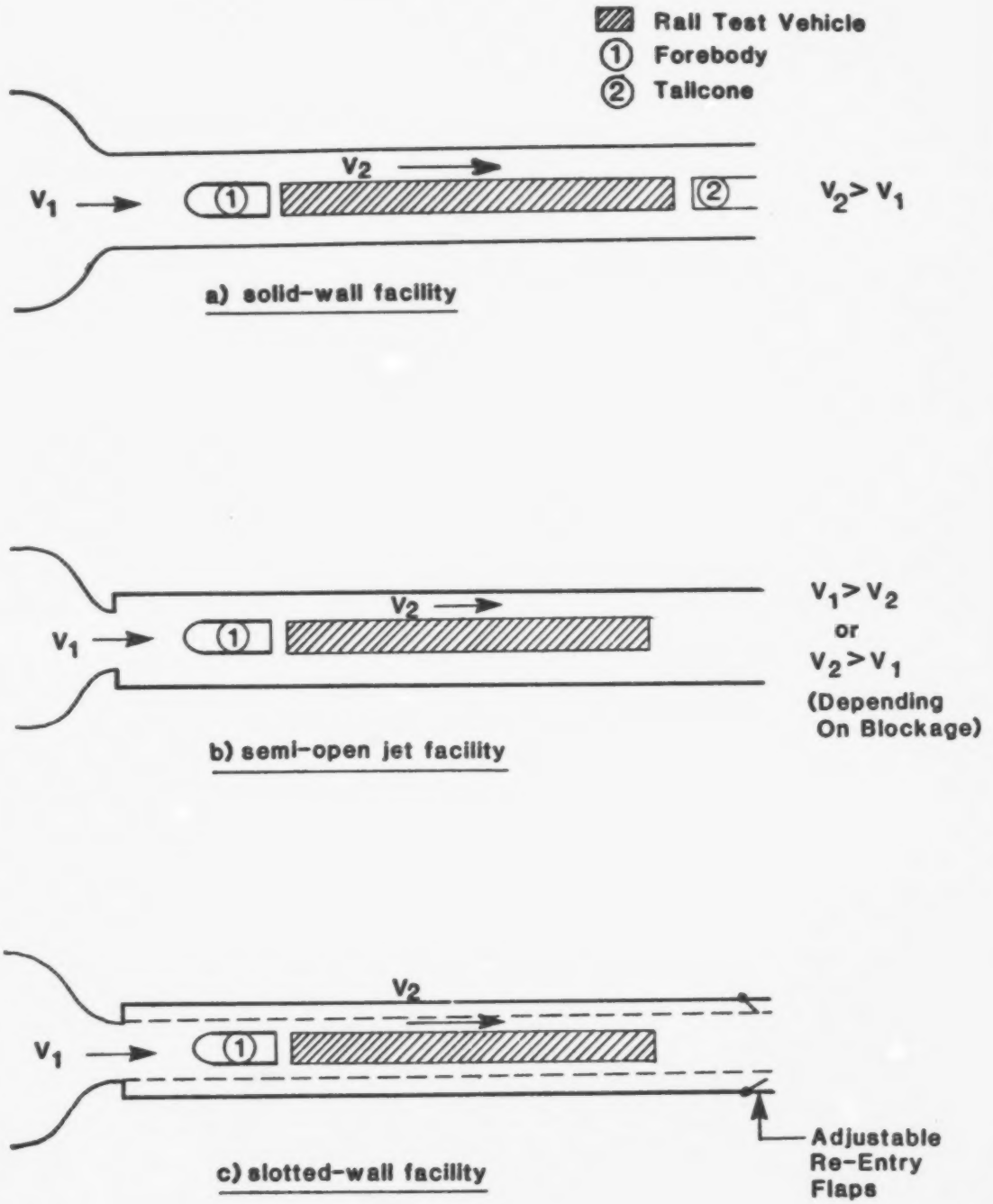


Figure 13 Test Section Configuration Options

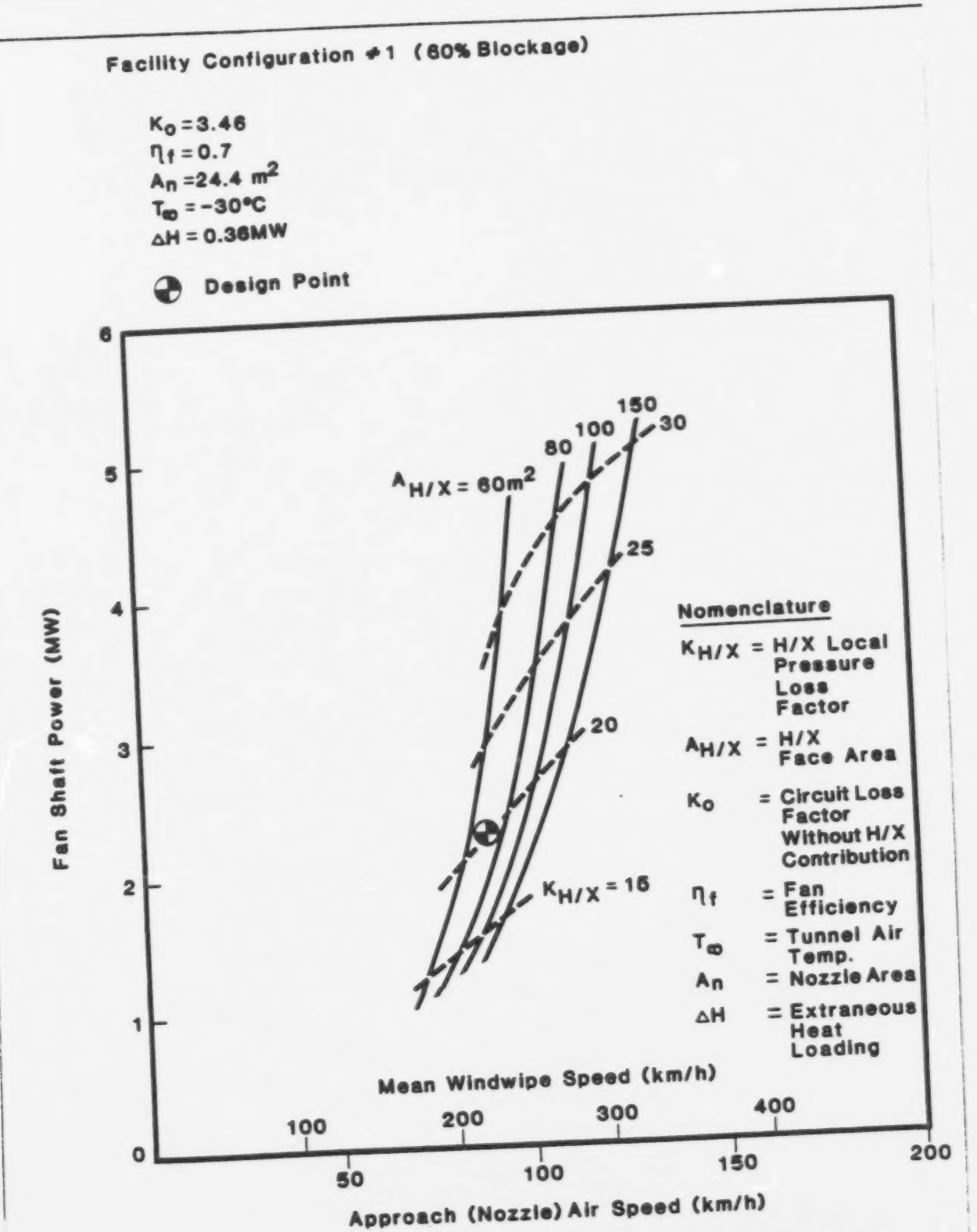


Figure 14. Fan Power/Heat Exchanger Evaluation

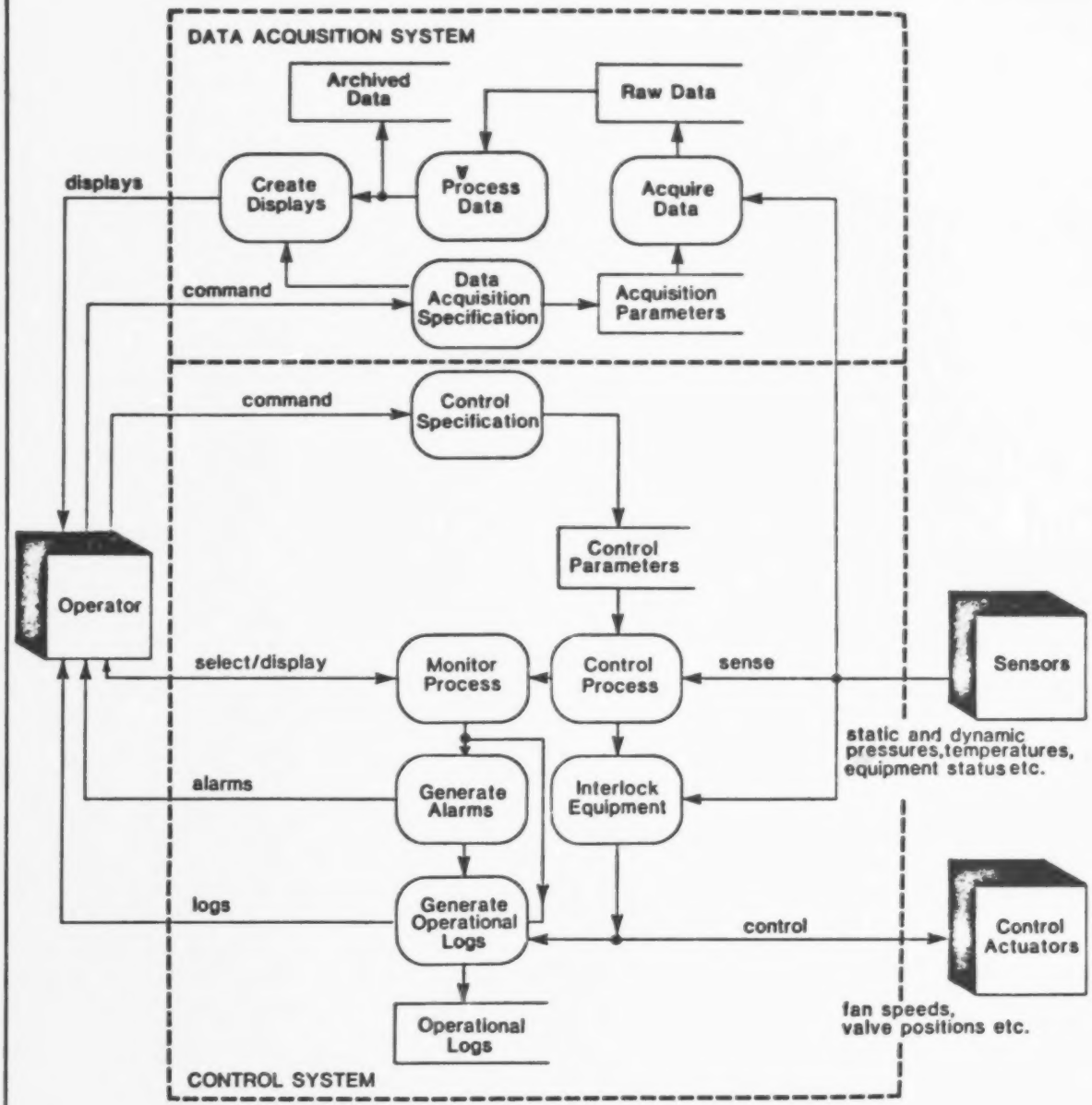


Figure 15 Facility Support System Schematic

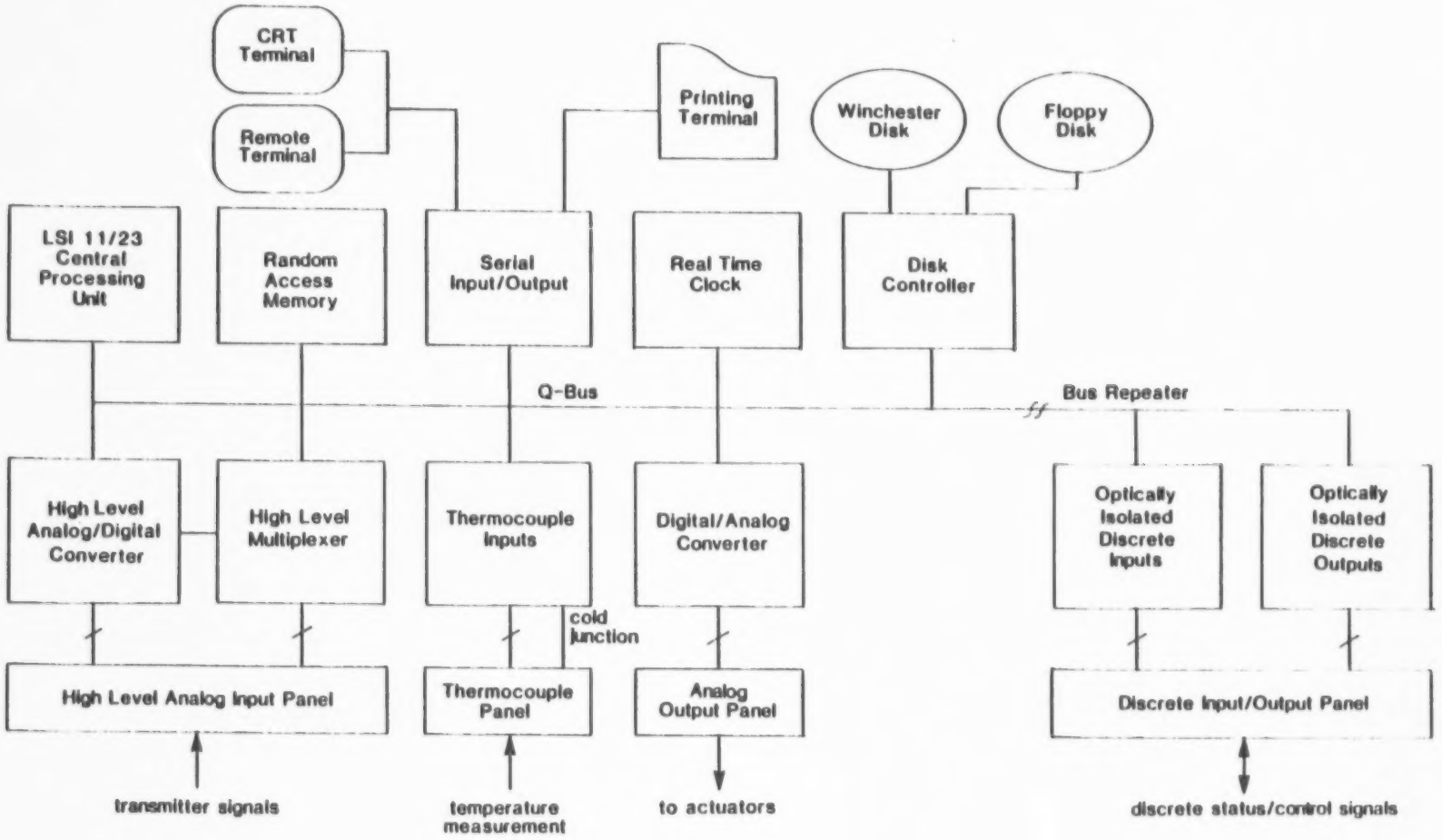


Figure 16 Control Computer Configuration

MIL-D-45123C(WC) PARA 3.4.1

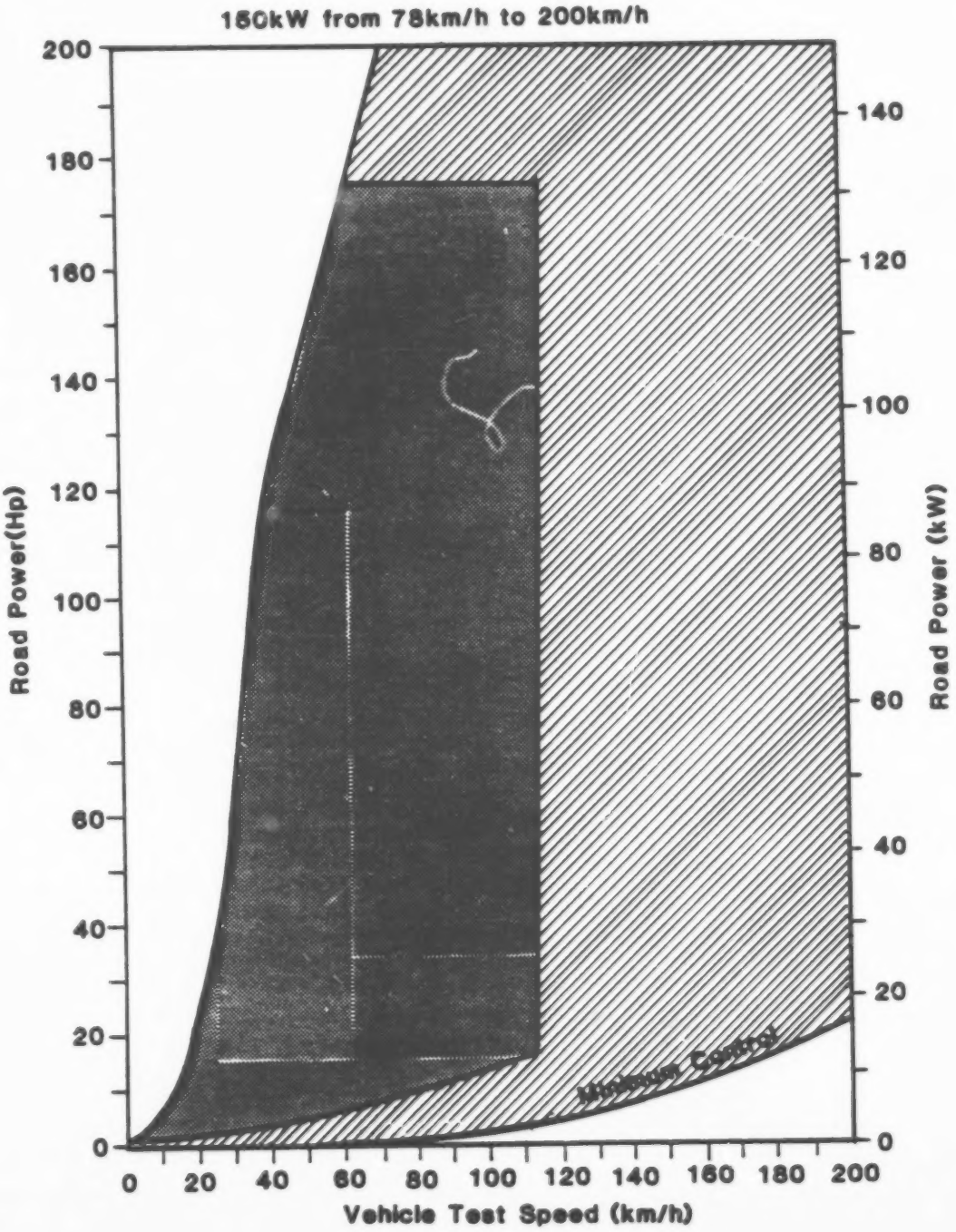
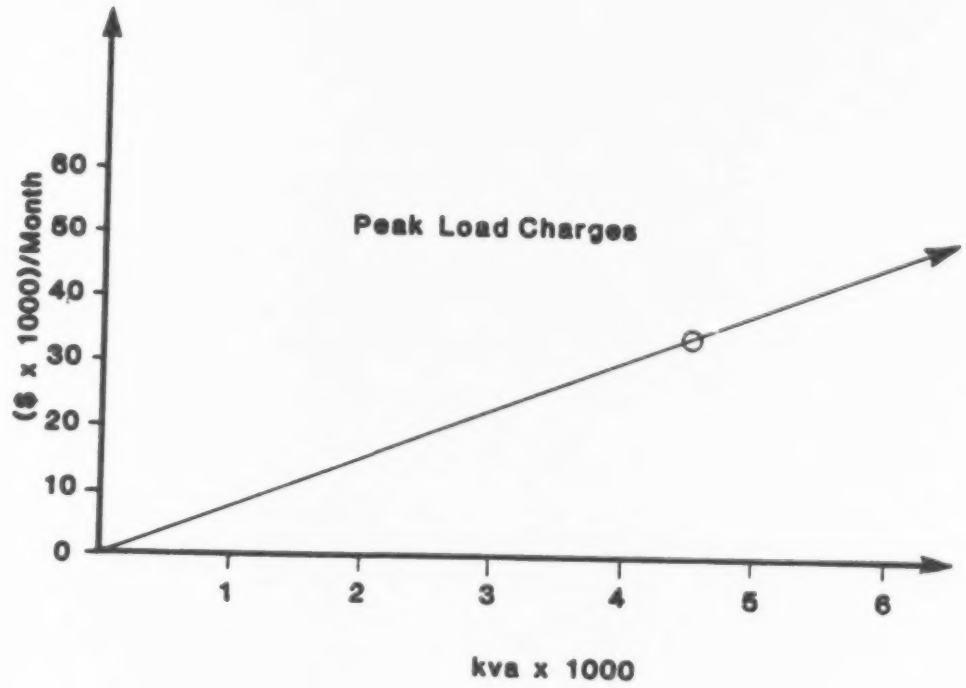


Figure 17. Clayton/AESI 150kW Absorber Load/Speed Profile



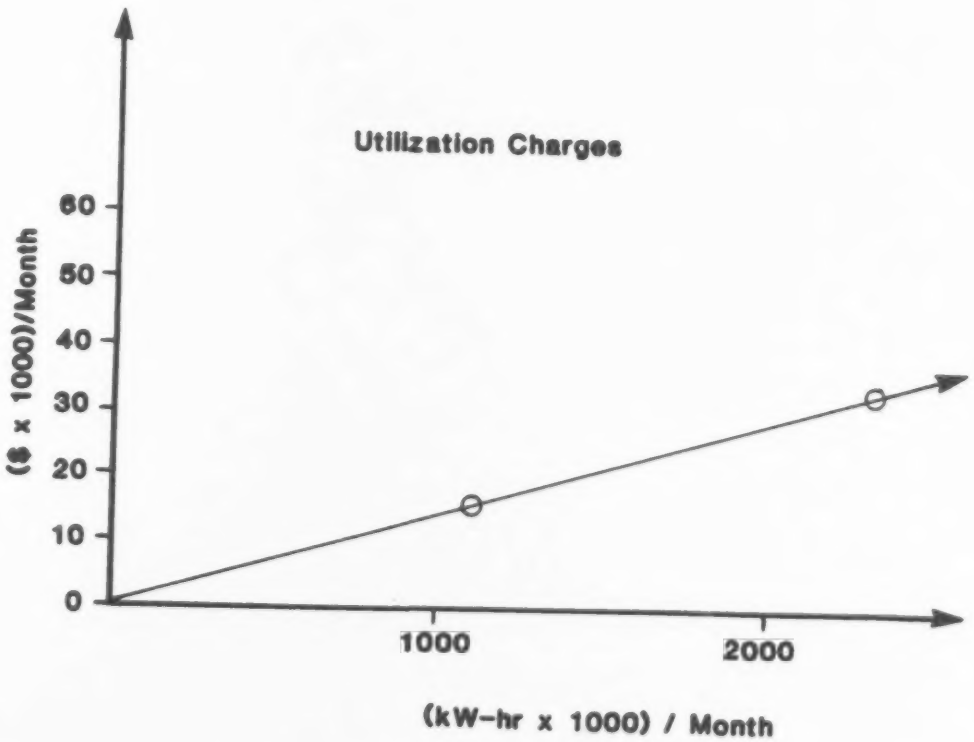


Figure 18. Electricity Cost Functions

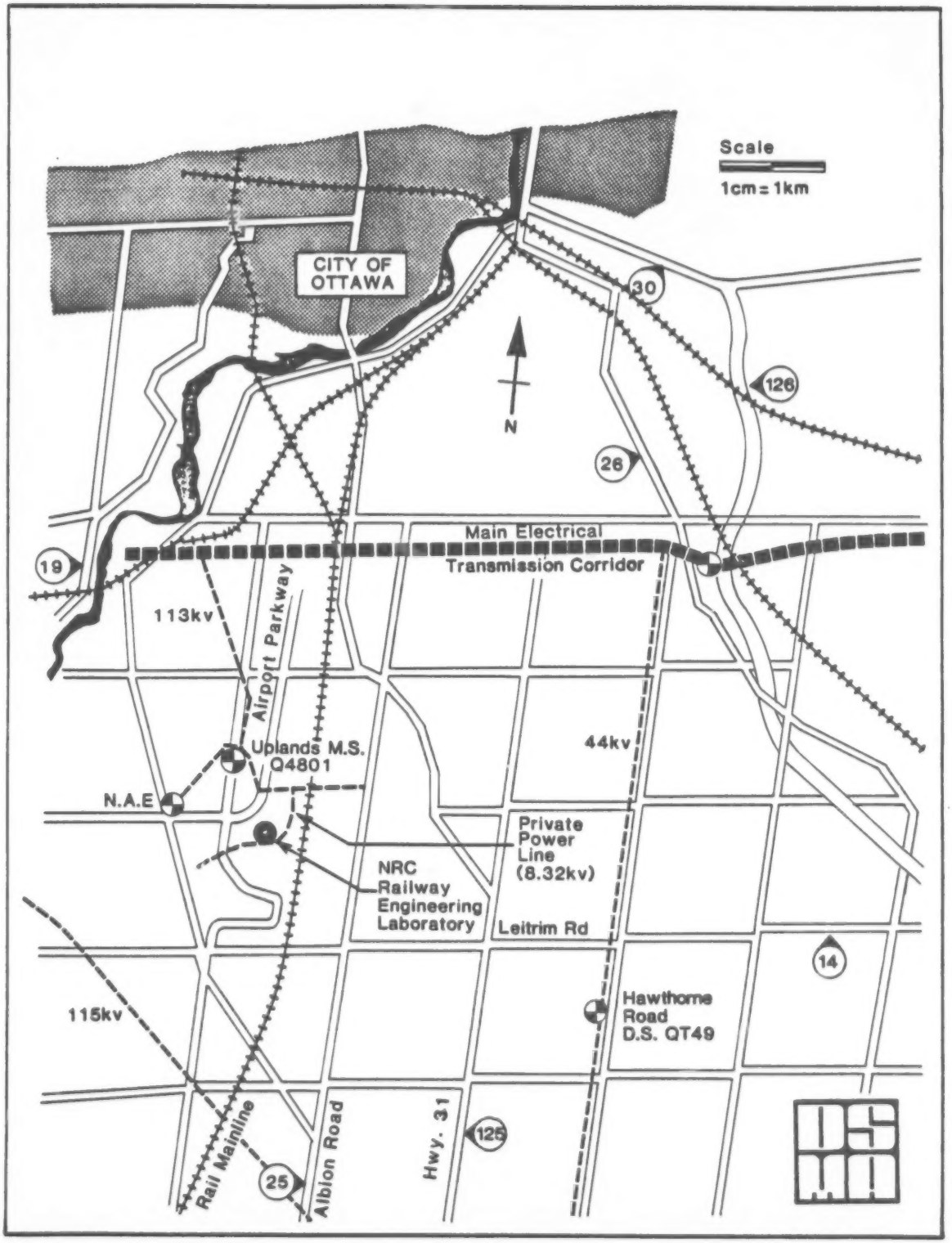


Figure 19. ELECTRICAL POWER SUPPLY ROUTE OPTIONS

TABLES

TABLE 1

INDUSTRY RESPONSES TO PRESCREENING QUESTIONNAIRE

Sector	Sent	Responses to Quest.1 Yes	No	Percentage Responding	Percentage of Respondents Who Said Yes	No. of Interviews
Road Transport	32	15	1	50	94	8
Off-Highway	38	27	2	76	93	9
Aerospace	12	8	2	83	80	2
Electrical	11	9	0	82	100	5
Railway	12	11	1	100	92	6
Marine	8	4	0	50	100	0
Petroleum, Mining and Materials Handling	23	8	4	52	67	0
Miscellaneous	4	0	0	0	0	0
TOTAL	140	83	10	66	89	30

Note: Question 1 on the prescreening questionnaire asked:

"Are any of your products subject to design constraints or operational problems as a result of exposure to adverse or varied climatic conditions?"

TABLE 2

FACILITY CONFIGURATION TEST SYSTEMS AND CAPABILITIES

Test System/Capability	Facility Configuration		
	1	2	3
Solid-Wall Test Section	X	X	X
Slotted-Wall Test Section		X	X
Humidity Control	X	X	X
Solar Simulation		X	X
Rain/Freezing Rain Simulation		X	X
Chassis Dynamometer			X
Air Make-up/Dehumidification			X
Vehicle Exhaust Extraction			X
Tunnel Purge System			X

TABLE 3

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

OPTIMISTIC SCENARIO - MINIMIZED OPERATING COSTS

	YEARS FROM START OF CONSTRUCTION												
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DAYS IN USE	0	0	0	30	40	50	60	70	80	90	90	90	90
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	72	72	72	72	72	72	72	72	72	72
REFRIG PLANT STAFF	0	0	0	56	56	56	56	56	56	56	56	56	56
DIRECT LABOUR	0	0	0	183	183	183	183	183	183	183	183	183	183
INDIRECT LABOUR	0	0	0	146	146	146	146	146	146	146	146	146	146
PEAK LOAD COSTS	0	0	0	462	462	495	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	26	35	44	52	61	70	78	78	78	78
HYDRO COSTS	0	0	0	488	497	539	547	589	598	606	606	606	606
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	898	906	968	977	1038	1047	1056	1056	1056	1056
TOTAL INVESTMENT	6917	6917	6917	898	906	968	977	1038	1047	1056	1056	1056	1056
REVENUE													
TESTING REVENUE	0	0	0	-60	-80	-100	-120	-140	-160	-180	-180	-180	-180
NET INVESTMENT	6917	6917	6917	838	826	868	857	898	887	876	876	876	876
OPER COST PER DAY	.0	.0	.0	27.9	20.7	17.4	14.3	12.8	11.1	9.7	9.7	9.7	9.7
NET PRESENT VALUE	6288	12004	17201	17814	18376	18923	19424	19908	20352	20759	21128	21466	21772

TABLE 4

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

INTERMEDIATE SCENARIO - MODERATE OPERATING COSTS

	YEARS FROM START OF CONSTRUCTION												
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DAYS IN USE	0	0	0	30	40	50	60	70	80	90	90	90	90
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	108	108	108	108	108	108	108	108	108	108
REFRIG PLANT STAFF	0	0	0	140	140	140	140	140	140	140	140	140	140
DIRECT LABOUR	0	0	0	303	303	303	303	303	303	303	303	303	303
INDIRECT LABOUR	0	0	0	242	242	242	242	242	242	242	242	242	242
PEAK LOAD COSTS	0	0	0	462	462	495	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	26	35	44	52	61	70	78	78	78	78
HYDRO COSTS	0	0	0	488	497	539	547	589	598	606	606	606	606
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	1114	1122	1184	1193	1254	1263	1272	1272	1272	1272
TOTAL INVESTMENT	6917	6917	6917	1114	1122	1184	1193	1254	1263	1272	1272	1272	1272
REVENUE													
TESTING REVENUE	0	0	0	-60	-80	-100	-120	-140	-160	-180	-180	-180	-180
NET INVESTMENT	6917	6917	6917	1054	1042	1084	1073	1114	1103	1092	1092	1092	1092
OPER COST PER DAY	.0	.0	.0	35.1	28.1	21.7	17.9	15.9	13.8	12.1	12.1	12.1	12.1
NET PRESENT VALUE	6288	12004	17201	17961	18658	19326	19938	20523	21059	21549	21995	22400	22769

TABLE 5

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

PESSIMISTIC SCENARIO - HIGH OPERATING COSTS AND LOW FEES

				YEARS FROM START OF CONSTRUCTION									
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DAYS IN USE	0	0	0	30	40	50	60	70	80	90	90	90	90
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	144	144	144	144	144	144	144	144	144	144
REFRIG PLANT STAFF	0	0	0	252	252	252	252	252	252	252	252	252	252
DIRECT LABOUR	0	0	0	451	451	451	451	451	451	451	451	451	451
INDIRECT LABOUR	0	0	0	361	381	361	361	361	361	361	361	361	361
PEAK LOAD COSTS	0	0	0	462	462	485	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	26	35	44	52	61	70	78	78	78	78
HYDRO COSTS	0	0	0	488	497	539	547	589	598	606	606	606	606
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	1380	1389	1450	1459	1521	1529	1538	1538	1538	1538
TOTAL INVESTMENT	6917	6917	6917	1380	1389	1450	1459	1521	1529	1538	1538	1538	1538
REVENUE													
TESTING REVENUE	0	0	0	-30	-40	-50	-60	-70	-80	-90	-90	-90	-90
NET INVESTMENT	6917	6917	6917	1350	1349	1400	1399	1451	1449	1448	1449	1448	1448
OPER COST PER DAY	.0	.0	.0	45.0	33.7	28.0	23.3	20.7	18.1	16.1	16.1	16.1	16.1
NET PRESENT VALUE	6288	12004	17201	18143	19005	19824	20573	21282	21931	22524	23063	23553	23989

DSMA International Inc.

TABLE 6

PRESENT VALUE OF INVESTMENT ($ X 1000) AT 10% REAL DISCOUNT RATE

Operating Cost Scenario	Facility Configuration		
	1	2	3
Optimistic	18,042	19,105	21,772
Intermediate	19,040	20,102	22,769
Pessimistic	20,270	21,332	23,999

NOTES:
1. Life of asset is 10 years after completion of construction.
2. Salvage value is assumed to be zero.
3. Other assumptions as per Tables 3, 4 and 5.

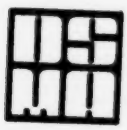


TABLE 7

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (K$1000)

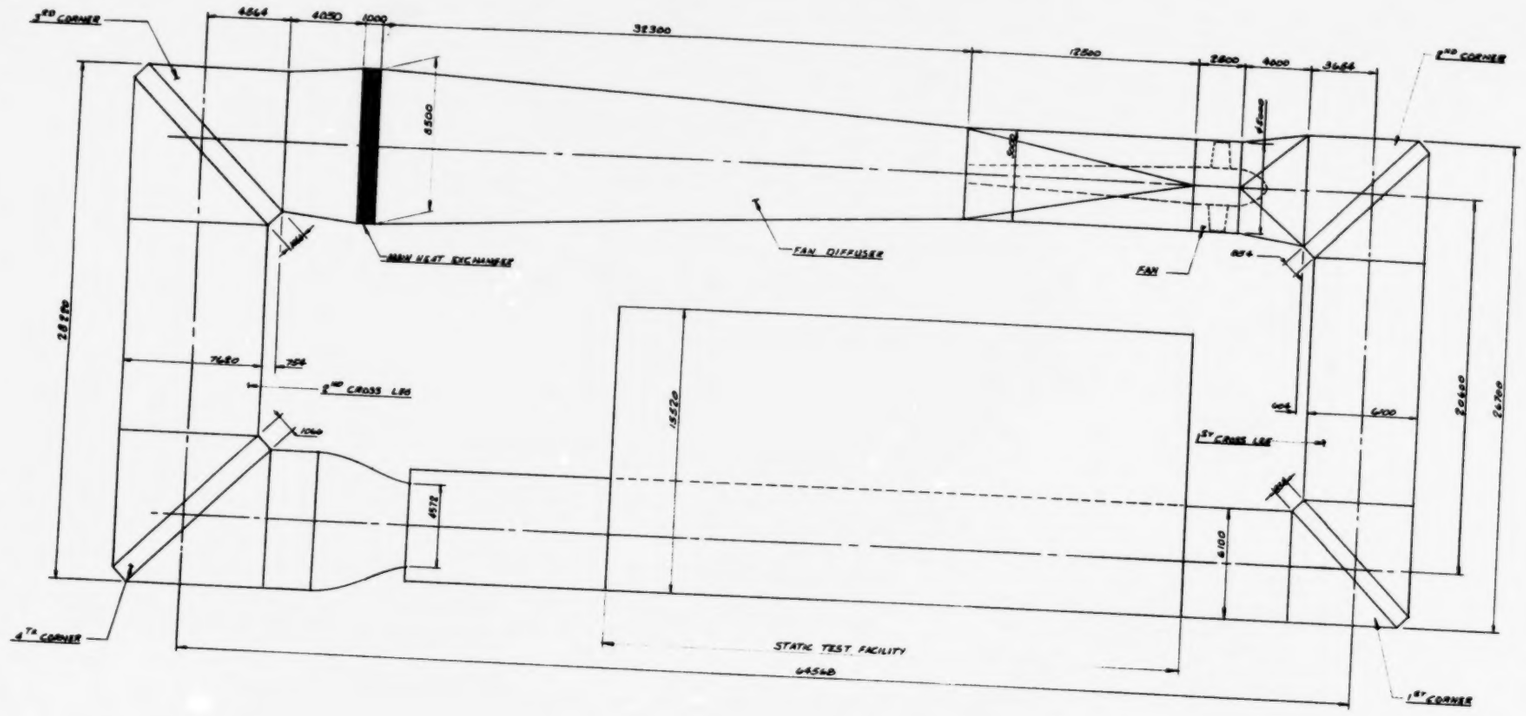
RESEARCH INTENSIVE SCENARIO - HIGH USAGE AND LOW OPERATING COSTS

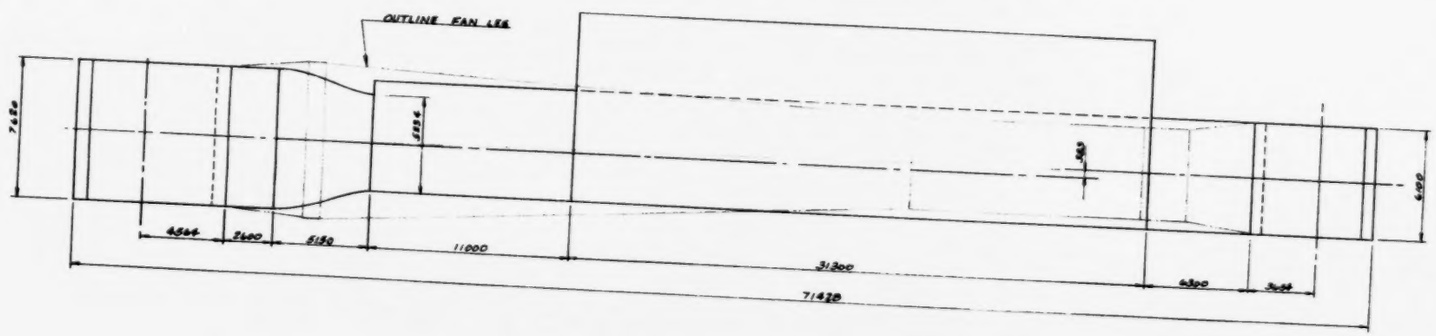
				YEARS FROM START OF CONSTRUCTION									
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	30	40	50	60	70	80	90	90	90	90
TOTAL DAYS IN USE	0	0	0	60	80	100	120	140	160	180	180	180	180
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	72	72	72	72	72	72	72	72	72	72
REFRIG PLANT STAFF	0	0	0	56	56	56	56	56	56	56	56	56	56
DIRECT LABOUR	0	0	0	183	183	183	183	183	183	183	183	183	183
INDIRECT LABOUR	0	0	0	146	146	146	146	146	146	146	146	146	146
PEAK LOAD COSTS	0	0	0	462	462	495	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	52	70	87	104	122	139	157	157	157	157
HYDRO COSTS	0	0	0	514	532	582	599	650	667	685	685	685	685
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	824	841	1011	1029	1099	1117	1134	1134	1134	1134
TOTAL INVESTMENT	6917	6917	6917	824	841	1011	1029	1099	1117	1134	1134	1134	1134
REVENUE													
TESTING REVENUE	0	0	0	-60	-80	-100	-120	-140	-160	-180	-180	-180	-180
NET INVESTMENT	6917	6917	6917	864	861	911	909	959	957	954	954	954	954
OPER COST PER DAY	.0	.0	.0	14.4	10.8	9.1	7.6	6.9	6.0	5.3	5.3	5.3	5.3
NET PRESENT VALUE	6288	12004	17201	17832	18416	18987	19515	20027	20501	20938	21336	21697	22025

DSMA International Inc.

DRAWINGS

DWG. NO. 4027 - 01





DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	NOTE	WT.

CONFIDENTIAL

MAT'L	AS DRAWN	REVISION

HORIZONTAL AIRLINE
(RECOMMENDED)

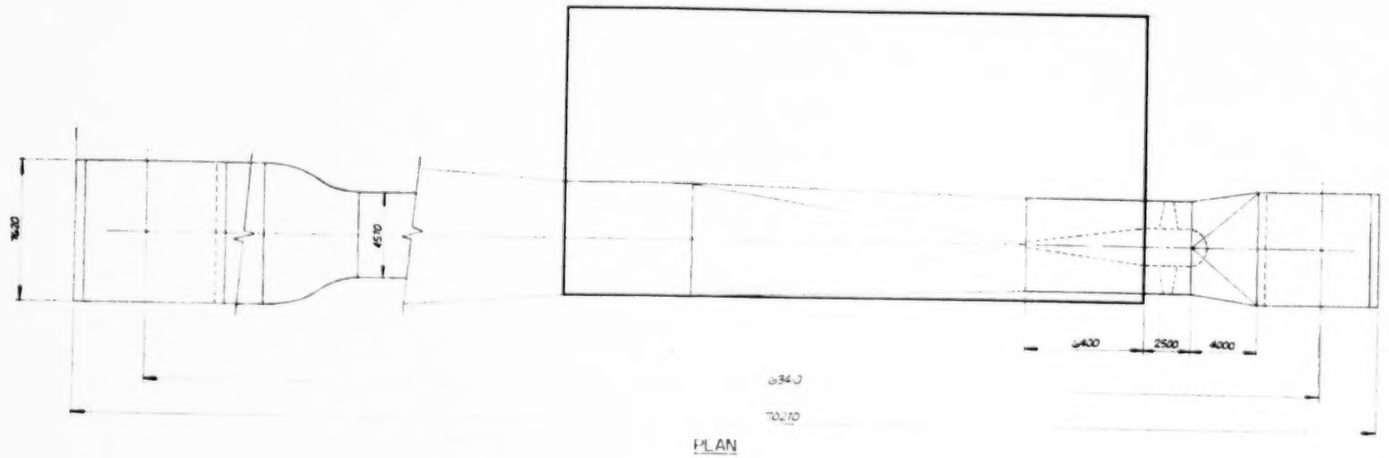
Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

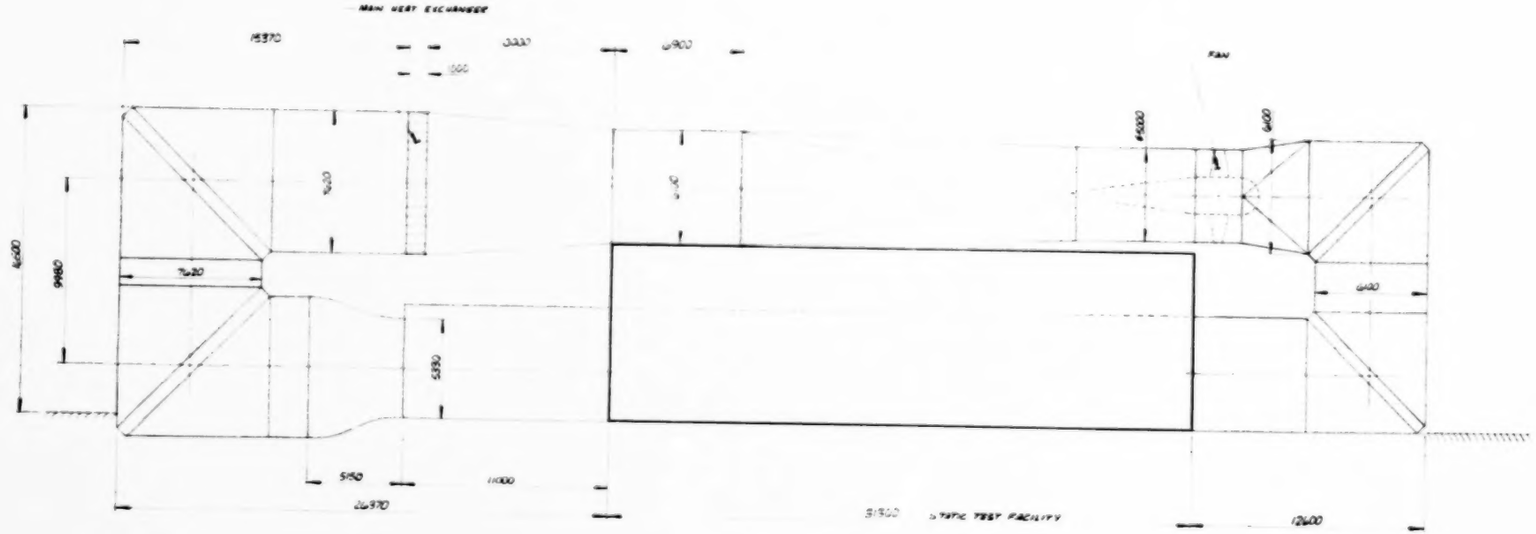
DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE 1:100		SIZE E	DWG. NO. 4027 - 01	SHEET 1 OF 1
4027				

E1 4027 - 02



PLAN



ELEVATION

BILL OF MATERIAL

ITEM QTY.	REFERENCE NUMBER	DESCRIPTION	QTY.

DWG. NO.	REFERENCE NUMBER

REVISION

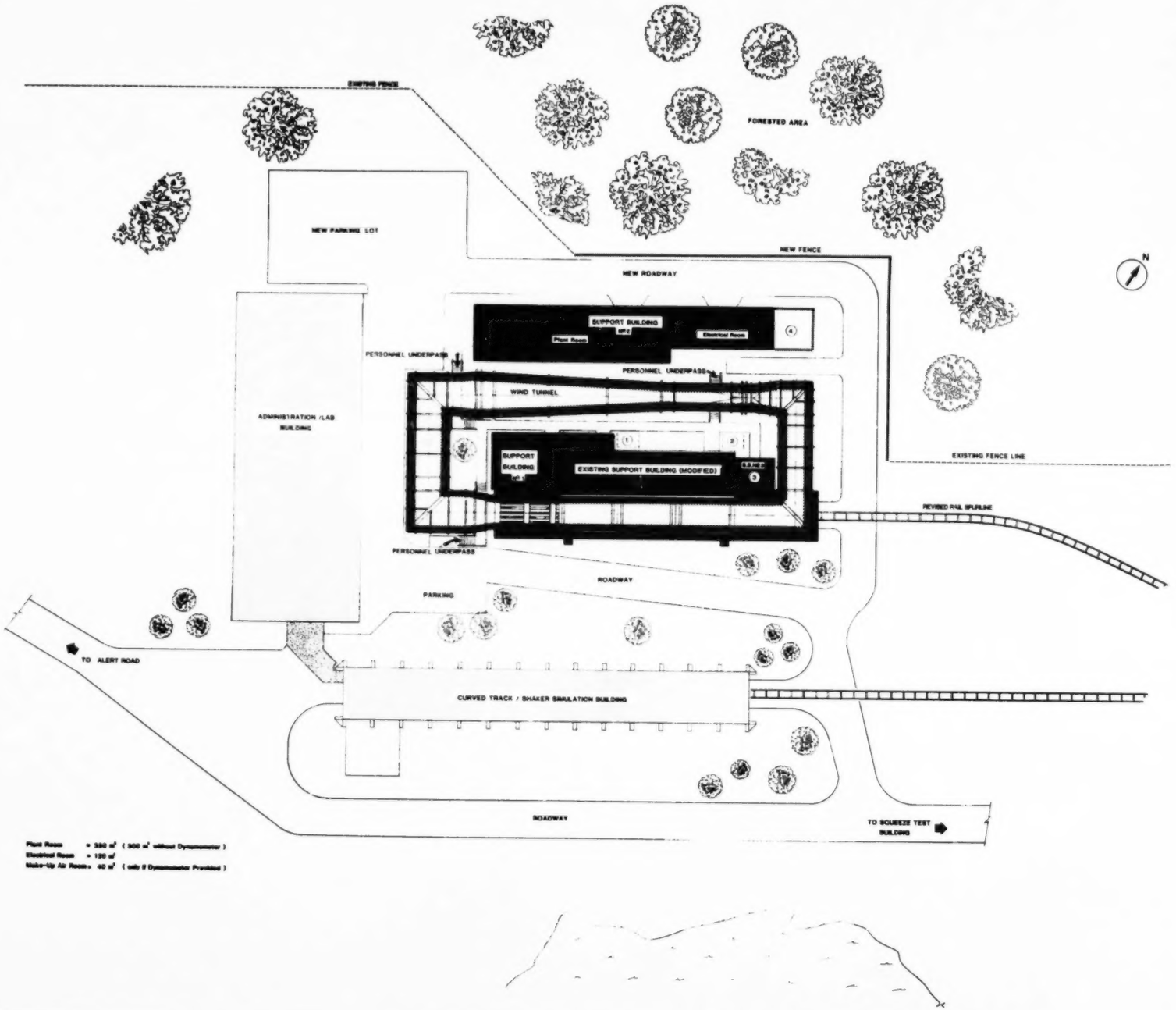
VERTICAL RETURN LOOP

Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE 1:100				SHEET OF SHEETS
DRAWING 4027	SECTION	SIZE E	DWG. NO. 4027 - 02	REV. 02



Plant Room = 560 m² (900 m² without Dynamometer)
Electrical Room = 120 m²
Make-Up Air Room = 40 m² (only if Dynamometer Provided)

DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	NOTE

NOTES

1. Condenser Pad #1 (NRC Static Facility) -relocated
2. Condenser Pad #2 (NRC Static Facility) -existing
3. Support Building for Make-Up Air Unit (optional)
4. Main Transformer Sub-Station

DWG. NO. 4027 - 03

NO.	BY	REVISION	CHKD	APPD	DATE
	J.T.	As Planned	R. Jones		

SITE PLAN

Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

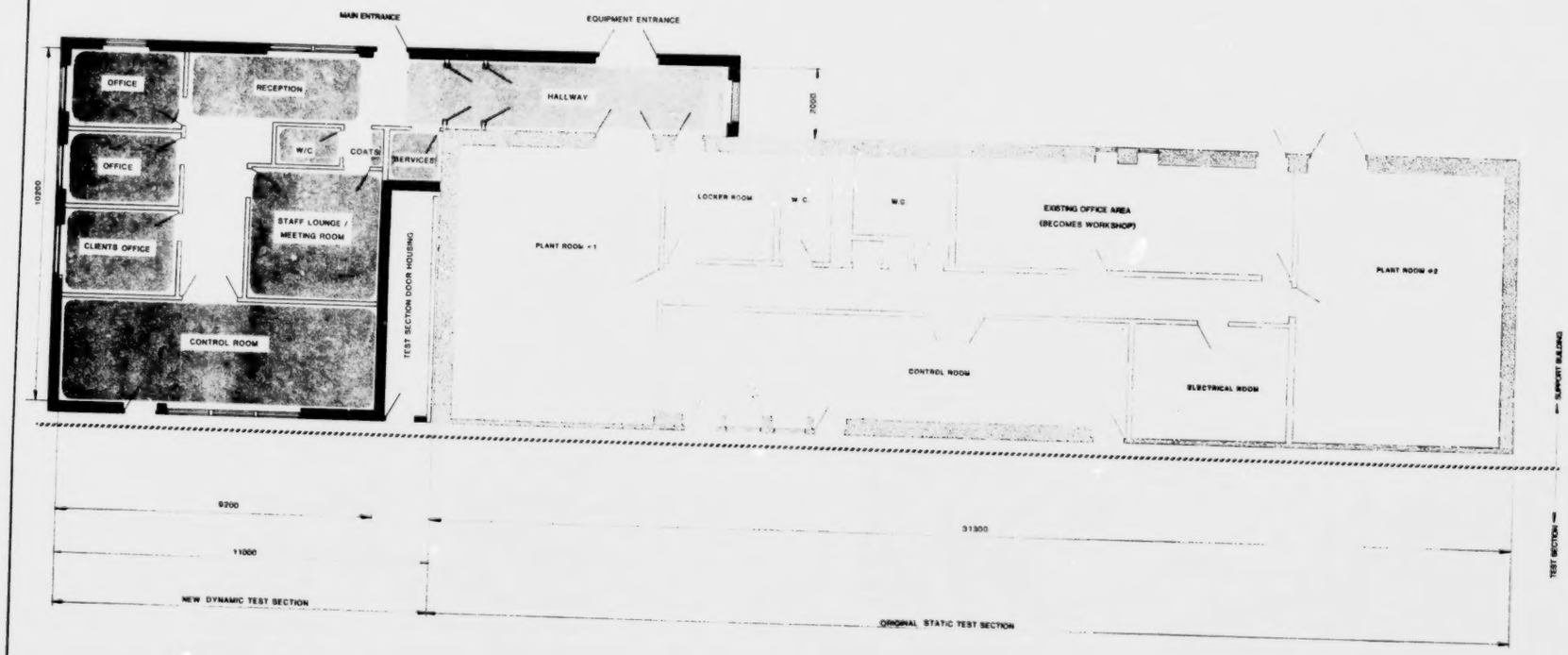
SCALE 1:250			DWG. NO. 4027 - 03	
PROJECT 4027	SECTION	SIZE E		

E | DWG. NO. 4027 / 04

DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	SIZE	WT.



NEW OFFICE BUILDING : 94 m²

EXISTING BUILDING : 393 m²

BY	As Drawn	REVISION		

PROJECTION: THIRD ANGLE

DRAWN: B. Jaa

CHECKED

APPROVED

SUPPORT BUILDING PLAN LAYOUT

Transportation Development Centre

Transport Canada

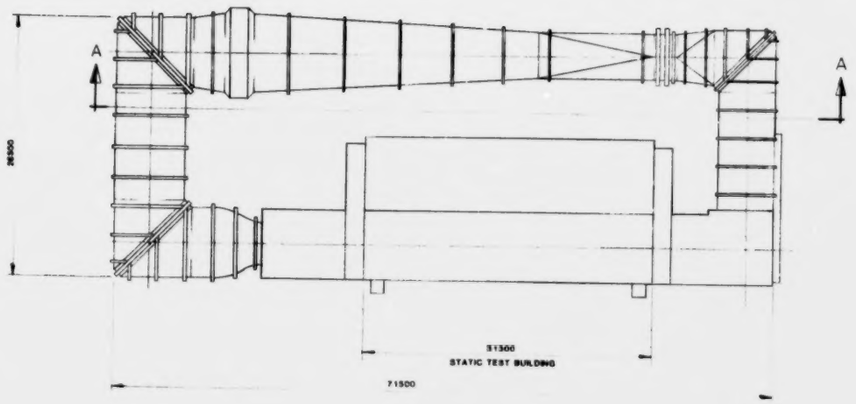
Dynamic Controlled-Climate Test Facility

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE	SHEET OF SHEETS
1:50	

PROJECT	SECTION	SIZE	DWG. NO.	ISSUE
4027		E	4027 / 04	12 Oct 81

SECTION A-A



PLAN VIEW

SIDE ELEVATION

BILL OF MATERIAL

QTY.	DESCRIPTION	MATERIAL	MARK	WT.

DWG. NO.	REFERENCE DWGS.

Transportation Development Centre
Transport Canada
Dynamic Controlled-Climate Test Facility

SHELL GENERAL ASSEMBLY

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE 1:200			
PROJECT 4027	SECTION	SIZE E	DWG. NO. 4027 - 06

REVISION

4027 - 06

E | DWG. NO. 4027-08

NEW SUPPORT BUILDING

EXISTING SUPPORT BUILDING

NEW TEST SECTION ACCESS DOOR

NEW CONTROL ROOM WINDOWS

TEST SECTION DOOR HOUSING

PIVOTING TURNING VANE ASSEMBLY

AIR FLOW

SLAT ASSEMBLY

SOLAR LIGHTS (OPTIONAL)

REMOVABLE SOLID WALL LINER

SLIDING DOOR (VEHICLE ACCESS)

BALLY PANEL PLENUM WALL

SLAT SUPPORT COLUMN WITH FAIRING

BALLY PANEL

RE-ENTRY FLAPS SET #1 (UPSTREAM)

RE-ENTRY FLAPS SET #2 (DOWNSTREAM)

NRC STATIC TEST CHAMBER

TYP HYDRAULIC ACTUATOR

SLAT

SLOT

TYP VIEWING PANEL (HEATED)

ACCESS DOOR IN SLAT ASSEMBLY

TYP HEATED VIEWING WINDOW (SET IN INSERT WALL)

10600
SLOTTED-WALL TEST SECTION
(PERMANENT)

31700
SOLID-WALL TEST SECTION
(INCORPORATES THREE REMOVABLE INSERT SEGMENTS)

DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	SIZE	WT.

REVISION					
E	T. H. Dawn				

TEST SECTION
GENERAL ASSEMBLY
(CONFIGURATION No. 2)

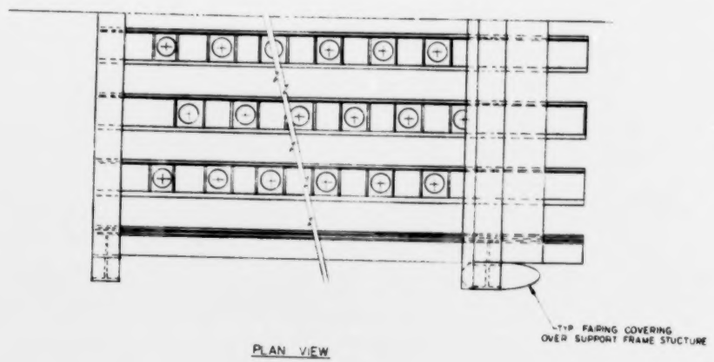
Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

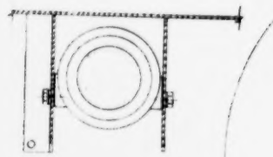
DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE	PROJECT	SECTION	DWG.	SHEET	OF	SHEETS	DWG. NO.	REVISION
1:80	4027		E				4027 - 08	

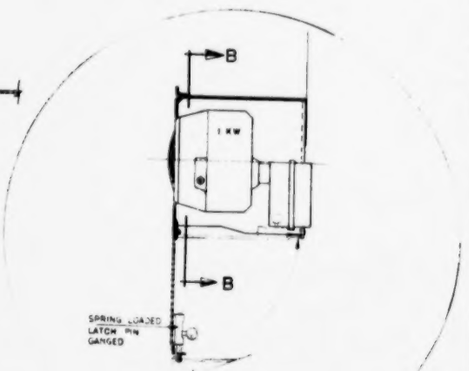
E | Dwg. No. 4027 - 07



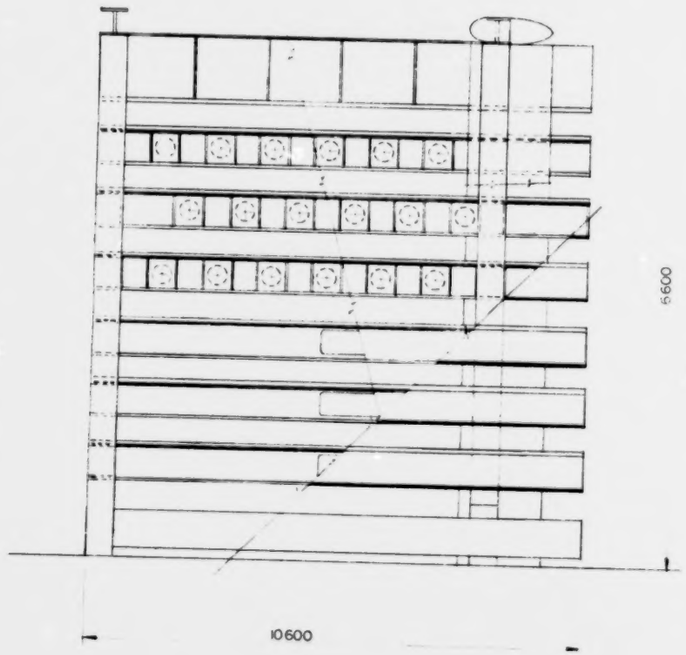
PLAN VIEW



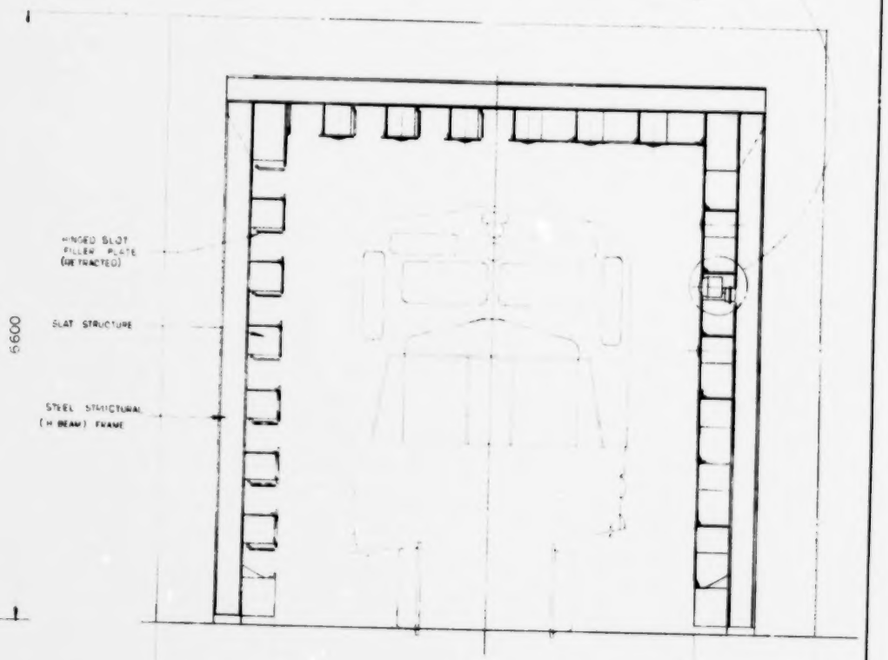
SECTION B-B
SCALE 1:5



SOLAR SIMULATION (OPTIONAL)
LAMP MOUNTING SCHEME
SCALE 1:5



SIDE ELEVATION VIEW



END VIEW
(LOOKING DOWNSTREAM)

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	NOTE	WT.

DWG. NO.	REFERENCE DWGS.

REVISION	BY	APP'D

PROJECTION: THIRD ANGLE
DRAWN: B. Field
CHECKED:
APPROVED:

NEW TEST SECTION
SLOTTED WALL ASSEMBLY
(CONFIGURATION N° 2)

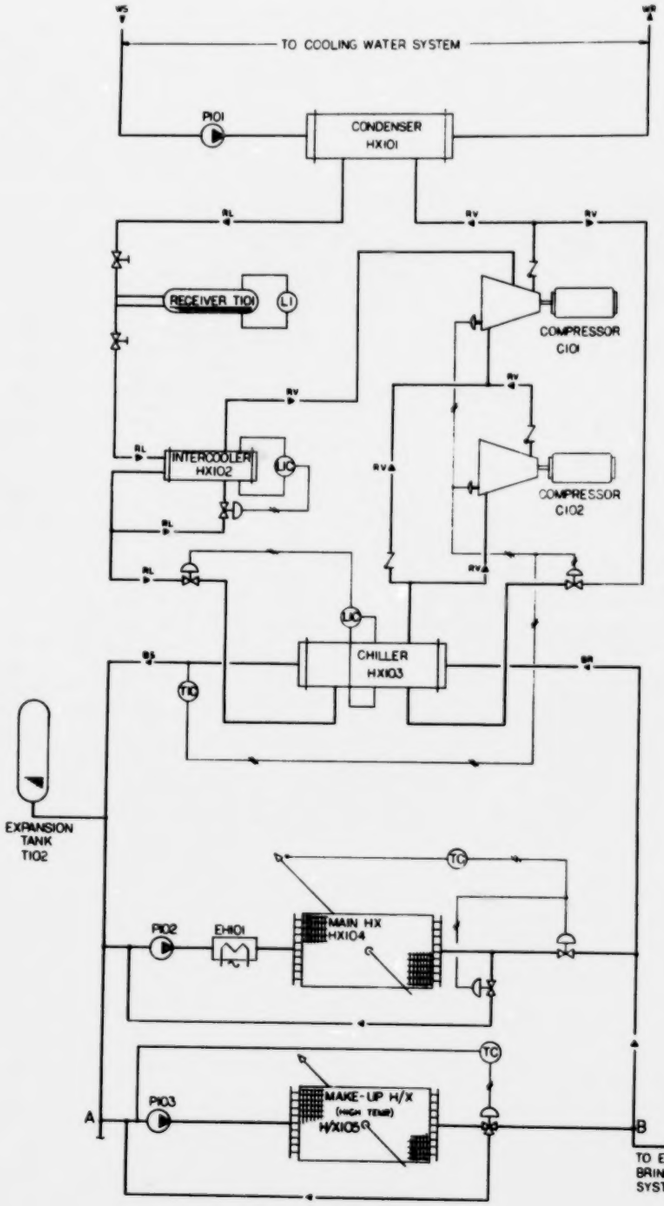
Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

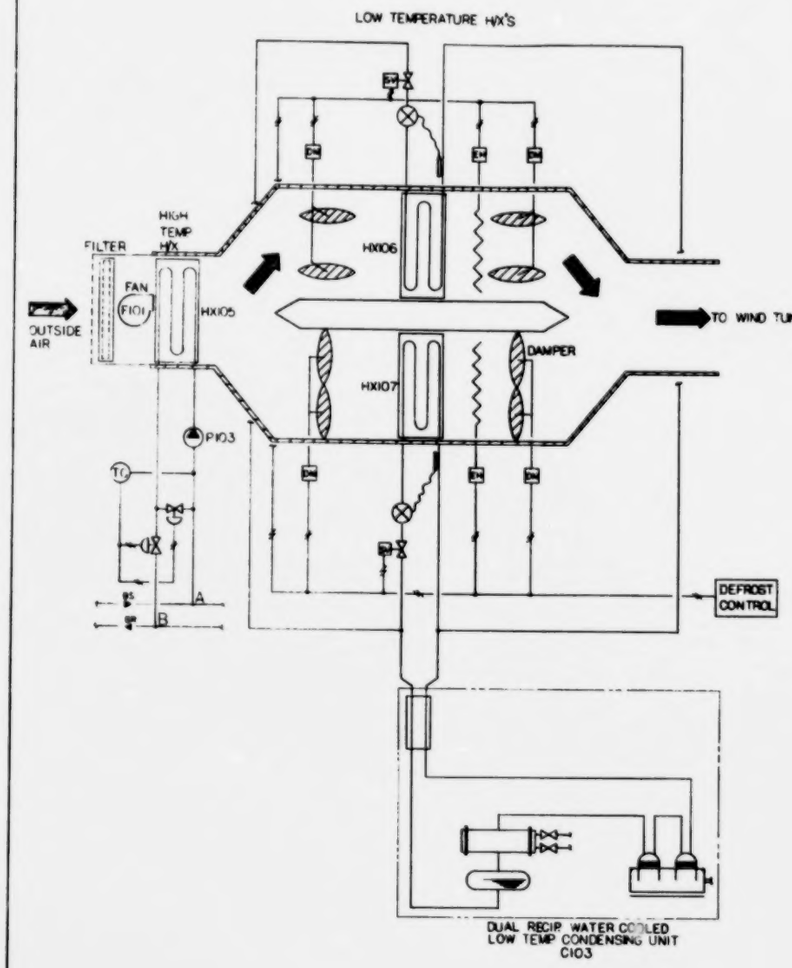
DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE	SHEET	SHEETS
1:20 & AS NOTED		

PROJECT	SECTION	SIZE	DWG. NO.	ISSUE
4027		E	4027 - 07	



MAIN REFRIGERANT AND BRINE SYSTEM



MAKE-UP AIR SYSTEM

LEGEND

- WS (R) — WATER PIPING — SUPPLY (RETURN)
- RL (V) — REFRIGERANT PIPING — LIQUID (VAPOUR)
- BS (T) — BRINE PIPING — SUPPLY (RETURN)
- LIQUID PUMP
- MODULATING CONTROL
- INSTRUMENT CONTROL
- CHECK VALVE
- HAND VALVE
- AUTOMATIC VALVE
- HEATER
- 3-WAY AUTOMATIC VALVE
- THERMAL EXPANSION VALVE
- DAMPER MOTER

INSTRUMENT/CONTROL IDENTIFICATION

FIRST LETTER	OTHER LETTERS
T - TEMPERATURE	C - CONTROLLER
L - LEVEL	I - INDICATOR

SV - SOLENOID VALVE
EH - ELECTRIC HEATER

NOTES

Transportation Development Centre
Transport Canada
Dynamic Controlled-Climate Test Facility

COOLING SYSTEM
FLOW DIAGRAM

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

4027 | E | 4027 - 08

SIZE E DWG. NO. 4027-09

27.6 kv SUPPLY

Main Substation

27.6 / 4.16 kv Transformer

Facility Configuration #1- 7500kva

#2- 7500kva

#3- 10000kva

Power Transformer

4.16 kv Switchgear

4.16kv 3 ph 60 HZ

Unit Substation

4.16 kv / 600 v Transformer

2500 kva (all)

4.16 kv / 600v

Isolating Transformer

3750 kva(all)

600v Switchgear

600v 3 ph 60HZ

Fan Drive System

Facility Configuration #1 2535kW

#2 2535kW

#3 2190kW

General MCC and

Power Distribution Centre

#1 695kW

#2 710kW

#3 725kW

Fan Auxiliaries MCC

200kw (all)

Refrigeration Low-Stage

Compressors and General MCC

#1 845kW

#2 845kW

#3 965kW

Refrigeration High-Stage Compressors

#1 1355kW

#2 1355kW

#3 3550kW

DWG. NO	REFERENCE DWGS

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	NOTE	ID

NOTES

1. Subsystem loads shown (kW) represent maximum individual loads for each subsystem under [illegible]

AS DRAWN

REVISION

ELECTRICAL POWER

DISTRIBUTION SCHEMATIC

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

Scale NTS

Sheet 1 of 1 Sheets

Project 4027 | Section | Size E | Dwg. no. 4027-09 | Issue 2

POOR

QUALITY

ORIGINAL